MINISTRY OF LABOUR

Conditions in Steel Foundries

FIRST REPORT OF THE JOINT STANDING COMMITTEE

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FOREWORD

Sir Wilfrid Garrett appointed a Committee in 1943 to consider the best methods of preventing either the production or the inhalation of dust in steel foundries and the possibility of reducing the use of materials containing free silica in steel foundry processes. The First Report of this Committee on Dust in Steel Foundries was published in 1944. At that time the Committee had completed a general review of the dusty processes and had agreed on recommendations in respect of some of them. It had become evident, however, that many difficult questions had been raised and that involved and probably prolonged investigation would be necessary before they could be answered.

After the publication of the Report in 1944 the Committee on Dust in Steel Foundries held a further 16 meetings and sponsored both research work and field investigations in an effort to assist the industry in the suppression of dust. In 1951 the Committee presented its Second Report which was published in order to inform the industry of the progress that had been made, the methods that had been used and the general lines of approach of the Committee. This Report indicated considerable progress in many ways, but the Committee remarked nevertheless that there were still many problems awaiting a solution.

In the following year a new Joint Standing Committee on Conditions in Steel Foundries was set up with wider terms of reference as follows:

"To keep under review conditions and developments in the industry affecting the health, safety and welfare of the persons employed."

The Joint Standing Committee has now completed this First Report which records a vast amount of work done over a period of 8 years. The document provides a comprehensive review of health and safety problems in the industry. The main text contains the views of the Joint Standing Committee, the Appendices summarise much of the original research and development work which has been done in an effort to solve individual problems and the bibliography is sufficient to enable original papers to be traced from 1944.

MEMBERS OF COMMITTEE

Mr. H. Woods, C.B.E., H.M. Deputy Chief Inspector of Factories, Chairman

EMPLOYERS' REPRESENTATIVES

Mr. R. Barber, British Steel Founders' Association
Brigadier A. Levesley, O.B.E., British Steel Founders' Association
Mr. F. N. Lloyd, Engineering and Allied Employers' National Federation
Mr. Frank Rowe, British Steel Founders' Association

TRADE UNION REPRESENTATIVES

Mr. F. Bullock, Amalgamated Union of Foundry Workers
Mr. T. Jones, Associated Society of Moulders and Foundry Workers
Mr. D. Scott, Amalgamated Union of Foundry Workers
Mr. J. H. Wigglesworth, O.B.E., Iron, Steel and Metal Dressers' Trade Society

INDEPENDENT MEMBERS

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Professor R. J. Sarjant, O.B.E.

BRITISH STEEL CASTINGS RESEARCH ASSOCIATION REPRESENTATIVE

Dr. A. H. Sully

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H.M. FACTORY INSPECTORATE REPRESENTATIVES

Dr. W. D. Buchanan, H.M. Deputy Senior Medical Inspector of Factories
Mr. W. B. Lawrie, M.B.E., H.M. Engineering Inspector of Factories

LIST OF FORMER MEMBERS

Mr. H. A. Hepburn, C.B.E., H.M. Deputy Chief Inspector of Factories, Chairman	1952–1953
Mr. T. W. McCullough, O.B.E., H.M. Chief Inspector of Factories, Chairman	1953–1956
Mr. R. Bramley-Harker, H.M. Deputy Chief Inspector of Factories, Chairman	1956–1958
Mr. W. A. Attwood, Secretary	1954–1958
Mr. J. Dobson, Member	1954–1956
Mr. J. F. B. Jackson, Member	1952–1955
Mr. H. McArthur, Member	1956–1958
Dr. A. I. G. McLaughlin, Member	1952–1958
Mr. E. L. Macklin, Member	1952–1956
Mr. D. W. L. Menzies, Member	1952

First Report of the Joint Standing Committee on Conditions in Steel Foundries

To: Mr. T. W. McCullough, O.B.E.,
H.M. Chief Inspector of Factories.

INTRODUCTION

General

1. The Joint Standing Committee on Conditions in Steel Foundries held its first meeting on the 24th April, 1952, and has continued to meet at regular intervals. Over the years there has been a number of changes in the membership of the Committee. A list of those who have previously served on the Committee is given above and we are glad to express our appreciation of the services of these gentlemen.

2. Some of our members had served on the earlier Dust in Steel Foundries Committee[1, 2] and, as a preliminary measure, we accepted the statements and recommendations of that Committee as a satisfactory basis for our own work. This allowed us to concentrate at once on the problems that had already been indicated by that Committee. Our own discussions produced further problems but we have, so far as dust is concerned, endeavoured to find practical methods by means of which the recommendations of the earlier Committee could be put into effect. Our terms of reference are much wider than those of the original Committee and our discussions have, in consequence, ranged over many matters which were not included in the earlier Reports. Our task is by no means ended but we think we should give you a report of the last seven years' work, even though many of the research and development projects were published as they were completed. We do this in the hope that you may see fit to publish this first report, because we think it desirable that the results of the work that has been done should have the widest possible publicity and, more important still, that they should be put into practice in the industry at once.

Activities of Employers

3. The British Steel Founders' Association has continued to work through its Committee on Industrial Health in Steel Foundries. Two of our members[4] attended meetings of its Sub-Committee for Practical Work until it was dissolved in May, 1956.

An earlier Report[2] indicated that the British Steel Founders' Association had organised a mobile radiographic service which tours the country so that member firms of the Association may arrange for their employees to have full plate X-ray photographs at periodic intervals. This unit is still in existence and the work has proceeded without interruption since the publication of the earlier Report[2]. Some reference is made to the work of this service in Appendix I.

The British Steel Founders' Association has also recently set up its own Accident Prevention Committee to study safety in steel foundries. A report of the work of this Committee will be found in Appendix II.

Activities of Research Associations

4. The British Steel Founders' Association, in order to facilitate research, set up in the early days of the work a research and development division[75] which later formed the basis of the British Steel Castings Research Association. This Research Association, which was formed about the time that the earlier Report[2] was published, has engaged in a great range of theoretical and experimental work on the control of the foundry environment. It has, in addition, conducted many field trials in conjunction with individual member firms of the Association. It has also continued to sponsor the pathological and biochemical work which was mentioned in the earlier Report[2]. This work is being done at the University of Reading in an effort to determine the toxicity to mice and rats of various mineral and foundry dusts and to study the development of silicosis. An examination is being made of the changes in lung tissue accompanying exposure to silica dust, alone and in combination with other constituents of dusts generated in foundries. The results have an important bearing on the mechanism and formation of fibrous lung tissue.

The Research Association also sponsored a conference on "Steel Foundry Dust Control and Ventilation" in 1955 at which much of its own work on the subject was published, together with relevant work from other sources.

Activities of Trade Unions

5. We are indebted to our trade union representatives for much assistance in keeping their members informed of the work we have had in hand. Mr. Wigglesworth, Mr. Gardner and Mr. Jones have all invited speakers from the Factory Inspectorate to their national conferences so that their delegates might have up-to-date information and the opportunity of discussing it. We are also indebted to these gentlemen for their assistance in ensuring close co-operation from the members of their Unions on those occasions when trial plant has been installed in foundries.

Official Activities

6. An official party consisting of Mr. H. A. Hepburn, Dr. A. I. G. McLaughlin and Mr. W. B. Lawrie had visited Scandinavia in October, 1950, to study foundry conditions. Their comprehensive report was of great assistance as it indicated, amongst other matters, the latest developments in Scandinavian foundry ventilation.

In the immediate post-war years prior to 1950 we maintained close contact with the Ministry of Supply in an effort to assist all parties in the difficult decisions involved in the issue of building licences and to ensure that proper standards were secured in new and rebuilt foundries. This activity ceased on the resumption of more normal conditions.

7. The Iron and Steel Foundries Regulations, 1953, were made under the Factories Acts, 1937 and 1948 by the Minister of Labour and National Service on the 1st October, 1953. We have discussed this code of Special Regulations in relation to our terms of reference.

Eye Protection

8. Our terms of reference include safety, of which eye protection is obviously a part. We are not, however, discussing this matter now because we know that

you have set up a separate Advisory Committee to deal with the problems associated with the use of goggles as protection against molten metal in foundries. We have noted the information about the work of this Committee which has already been made available to the industry and to the technical press[61, 81].

The Garrett Report

9. At our second meeting we agreed to accept the report[5] of the Joint Advisory Committee on Conditions in Iron Foundries, commonly known as the Garrett Report, as a basis for the steel founding industry.

DUST

General

10. A large proportion of our work has been concerned with dust but before proceeding to a discussion of this work, we must make certain general observations.

We have given, and we are still giving, a good deal of attention to methods of observing and estimating dust clouds. Part of this section of the work is experimental and part is theoretical and much of it may seem to be divorced from foundry practice. We are certain, however, that this work is necessary, even though we have no doubt that our main object is to suppress the dust. We are not engaging in pure research and when we have diverged from the practical requirements of our terms of reference, we have done so only to construct the necessary tools to do the work that must be our prime concern. In this connection we think we should quote from the earlier Report[2] to stress the point. "Much of our effort has inevitably been given to the measurement of dust clouds. It is important, however, to point out that the science and practice of dust determination is not an end in itself but a means to an end. Necessary as the dust determinations are, in order to be able to assess results, the essence of our work is dust suppression."

11. It is generally considered that dust particles less than 5 microns* in diameter are the most dangerous to health and it is known that free silica particles of these sizes are the cause of silicosis while other dusts may give pneumoconiosis. Much of our work therefore has been devoted to the suppression of dust within this size range. We use the term "dust suppression" in the sense in which it was used in the earlier Report[2] to include every method by means of which unwanted dust clouds could be removed from the breathing zone of the operators. These methods can be divided into two broad groups as follows:—

(1) The elimination of the dust, and

(2) The control of the dust.

In all our work we have adhered to this logical sequence applying each group of methods in turn. The first group is always the best although it is generally the most difficult, but even when all the dust cannot be eliminated it is always worth-while to eliminate as much as possible. This is especially true in the case of dangerous fractions of a dust cloud and these should always

* 1 micron$=\frac{1}{1,000}$ mm. $\simeq \frac{1}{25,000}$ inch.

be eliminated where it is practicable to do so. We have no doubt that the second group of methods will continue to be the only practicable one in many cases for a long time to come but we are quite satisfied that every dust problem should be examined in this manner and that even though it represents manifest long-term policy in steel foundries, every effort should be made to eliminate dust at source by "preventing the production of the dust".

Preliminary Dust Estimation

12. A rapid method of dust estimation which was published in 1948[6] was adapted for use in steel foundries and described in an earlier paper[7]. The Owens Jet Counter was chosen as a sampling instrument[8] and a number of foundries were surveyed and some of the results were published[9]. Statistical work[10, 11] on the dust surveys indicated certain anomalies, one of which was the suggestion that local exhaust ventilation as applied to certain pedestal grinders appeared to have no effect on the dust of respirable size range in the breathing zone of the operator. These dust particles, which are less than 10 microns in diameter, are invisible in ordinary lighting conditions and so the work which was described in some detail in an earlier Report[2] led the Dust in Steel Foundries Committee to the view that great benefit would accrue if the dust clouds could be seen and a member of that Committee then devised a method by means of which dust within the respirable size range could be both seen and photographed on cinematograph films[12].

Observation and Photography of Dust

13. The preliminary work on the observation and cinematography of dust[12] was just completed at the time of the publication of the earlier Report[2] and reference was made to it in that document. Since those days the technique has been widely used in development projects in a variety of industries and some account of the method is given in Appendix III.

14. The original work[12] showed that the fine dust left the point of a pneumatic chisel in the form of a plume which moved along the work a very short distance before turning upwards to follow the line of the chisel and rise up the operator's arm to his face. This effect can be seen from Figure 1 (see page 39) which was taken from the original film negative. It was also apparent that the anomalous results obtained when dust sampling on the pneumatic chisel had been caused by the fact that the cloud was hitherto invisible, which had in turn meant that it was entirely fortuitous whether the sampling instrument was in the cloud or only near to it. The original work[12] also showed that the conventional exhaust system as applied to pedestal grinders was not always as efficient as had been supposed. Figure 2 (see page 40) taken from the first film negative shows the dust being ejected from the opening between the top of the guard and the wheel, even when a conventional local exhaust ventilating system was fitted and operating. Figure 3 (see page 40) is also taken from the first film negative and shows the dust distribution observed when a portable abrasive wheel was used to grind a flat surface in still air in laboratory conditions. This photograph shows that a large proportion of the dust of small size range did not follow the line of sparks but flowed over the wheel top and appeared as a vortex between the wheel and the operator's face.

This technique for the observation and photography of moving dust clouds within the respirable size range has formed the basis of many of our research

and development projects and the dust photographs in this report were taken by means of it.

The Assessment of Dust

15. The early results[9] obtained from the rapid dust estimation method[6] showed that conventional local exhaust ventilation was not always satisfactory on pedestal grinders, they brought to light certain anomalies when dust sampling on pneumatic chisels and in consequence they led one of our members to develop the observation and photographic technique[12] which has since been so widely used in development projects. There was, however, still no satisfactory method by means of which dust levels could easily be estimated in foundries and so the British Steel Castings Research Association has given a good deal of attention to the assessment of airborne dust clouds in steel foundries. Some of this work is referred to in Appendix IV.

16. Dust samples may be taken with a view to determining the health hazard or they may be taken for the purpose of indicating the efficiency of devices that have been installed to suppress the dust. For the former purpose, it is necessary to know, with some accuracy, the quantity, nature and size of the particles constituting the cloud. It has been conventional to regard the Thermal Precipitator as a standard instrument but, even though it indicates the quantity of dust in particles per cubic centimetre of air and also gives the size range of the dust cloud sampled, other methods must still be used to determine the nature of the particles, and the Thermal Precipitator involves considerable expenditure of time and labour by relatively skilled microscopists.

17. When dust samples are taken to indicate the efficiency of dust suppression devices, the information required from them is somewhat different from that required by medical men. The practical approach is to suppress as much dust as possible on the assumption that this will also suppress the dangerous fraction. This means that engineers and foundrymen engaged in this work may require less information from the dust determination. One thing that was badly needed in the early days of the work was some simple and relatively accurate method by means of which changes in dust concentrations could be determined quickly and easily and if possible by men who are not particularly highly skilled in special techniques.

18. The Owens Jet Counter and the Konimeter were used for the early work because they gave instantaneous samples. Large numbers of these "snap" samples enable fluctuations in a dust cloud to be closely followed and this may be of some importance in the development of new methods of dust control. The rapid estimation technique[6] was in fact originally used to explore variations of dust concentration in time and space.

19. In addition to detailed information on dust fluctuations at particular processes, it is also desirable to know something about the general dust concentrations existing in foundries. In consequence an effort has been made to develop suitable methods of establishing dust levels in the industry.

20. The use of statistical surveys[6, 9, 11] showed that variations in dust levels could be established from day to day, from week to week, from process to process and between different foundries. It became evident, however, that

every such survey must be carefully planned in conjunction with a competent statistician and the statistical analyses were neither quick nor easy.

The British Steel Castings Research Association and other Organisations have developed a continuous sampling Thermal Precipitator[13, 14] in an effort to obtain general dust levels over relatively long periods of time, and the Association has also sponsored work on automatic counting by means of the flying spot microscope[18].

Finally, the British Steel Castings Research Association has also used the Hexhlet filter[15] which takes a sample large enough for chemical analysis and which can be estimated by weight. The instrument is so constructed that the sample it collects is reasonably similar to the dust which might be breathed and the estimation by weight is much easier and more convenient than the count method (see Appendix IV).

21. In general, dust samples are evaluated by one of three methods. The particles may be counted, the total surface area may be estimated or the sample may be weighed. Whichever parameter is used the samples should be estimated only on those particle sizes which fall within the respirable range. It has been shown[13] that the results obtained by the three methods can be co-related only if the size-frequency distribution of the samples remains constant. If, however, the range of particle size varies widely, the different methods of assessing the samples will give different results. The measure of mass concentration is easier and quicker than the count method and has the further advantage that long-term samples can be taken, thereby reducing the need for statistical treatment of the results. Count methods using "snap" sampling instruments are mainly useful for the study of the variation of dust concentrations with time and in space, and automatic counting to which reference has already been made is being developed in an attempt to facilitate the use of the count method.

22. The use of the observation and photographic technique[12] showed that many of the very heavy dust clouds that are formed by foundry processes are local in character and follow a well-defined path through space. The work also showed that many of these dust clouds were intermittent and that whilst they were dense while they lasted and might appear frequently in a working day, they might also dissipate rapidly at the cessation of the process which produced them. This very wide fluctuation in dust concentrations with time and space in a foundry adds to the difficulty of obtaining samples which may be considered as representative of the atmosphere. It is evident that a careful study will have to be made of the air flow pattern in each foundry building in order to select the best sampling position for the general foundry atmosphere and the British Steel Castings Research Association has given a good deal of thought to this aspect of the matter.

The Elimination of Dust

23. We can do little more than emphasise the views of the Dust in Steel Foundries Committee as set forth in the earlier Report[2]. As we have already remarked, we consider that the best way of dealing with undesirable dusts is to stop making it. This can only be long-term policy in the steel founding industry, but it is of the highest importance. So far as the dressing shop is concerned it means producing a better strip in the foundry and in consequence such matters as

sand practice are paramount. The British Steel Castings Research Association is engaged on this and similar aspects of steel founding and we hope that the Industry will take full advantage of their work so that every steel foundry dressing shop will be given a minimum quantity of dust to handle.

24. Much of the work on dust elimination must of necessity be done by research workers but there is a good deal that can be done only by practical men. We do not propose to discuss foundry practice in detail but, like the earlier Committee[2], we must emphasise the importance of craftsmanship. We know that founders want to make good castings for every reason but we are concerned here to stress the fact that good castings which require the minimum of dressing tend to the best conditions in the dressing shop. Technical control of moulding sand and moulding practice should always be given the fullest attention in order to avoid "burnt on" sand.

Dust control in the jobbing foundry is a very real problem and certain processes such as rubbing down large cores during closing, easing or slackening after casting and knocking out or stripping of heavy loam or pit moulds have always been regarded as dusty jobs. The knock-out or stripping processes are often particularly dusty. This difficulty in controlling dust in these heavy foundries stresses the need for close attention to all founding practices by which dust can be eliminated. No simple solution of this problem is available and indeed, it may only be solved if and when techniques and methods can be changed. This will only be done slowly over the years as new ideas are approved in practice, but every fresh suggestion warrants a trial and the final answer depends on a constant examination of every detail of day to day practice. In this connection we noted with interest a recent Iron Foundry paper in which the author described a method of making, in boxes, moulds which had previously been made in pits[19].

The standard of general ventilation should be high and where possible, the dusty work should be segregated in time (e.g. by working at night) so that the dust would be produced when the smallest number of men would be in the foundry to breathe it.

25. The use of wet cleaning methods eliminates a large amount of the dust associated with the stripping, de-coring and preliminary cleaning of large castings before the dressers get them. In particular a high water pressure, with or without a suitable abrasive, has been found to clean the castings and at the same time suppress a good deal of the dust normally associated with this process.

26. The British Cast Iron Research Association recently published a description of a wet de-coring bar which has proved very satisfactory on certain iron castings. Its use may well be limited to particular castings, but this kind of device is always worthwhile even if it only serves over a restricted field[20]. (See Appendix V.)

27. Like the earlier Report[2] we must refer to the real need for good housekeeping in steel foundries. Many foundries still need a much higher standard and we are convinced that even the best foundries cannot afford to ignore this aspect of the matter. This involves everybody in the foundry, demanding the most wholehearted co-operation of management and men.

28. The question of floors was also discussed in the earlier Report[2] and we agree entirely that one of the most important factors in maintaining a clean foundry is the provision of a hard and level floor wherever this is possible. Floors can only be swept and kept clean if they are constructed of concrete, brick, tarmacadam, wood, steel or iron plates or other suitable material and this should always be the case except where the provision of a sand floor can be shown to be necessary. We think that floors should be swept at least daily and that they should be damped before sweeping.

Whilst there is no necessity to use a concrete floor, there has been some doubt expressed as to the wisdom of using this material in foundries where molten metal may be spilt upon it. We think therefore that we should draw attention to refractory concrete which will withstand the thermal shock of molten metal.

The Elimination of the Dangerous Fraction of the Dust

29. When the total dust cloud has been reduced as far as possible by the elimination methods the next step is to examine the possibility of eliminating the dangerous fraction of the dust in those cases where the total cloud cannot be eliminated. We are here simply following the recommendation of the earlier Committee[2] which we consider to be quite sound and indeed to which we can add but little in this connection. The use of silica flour as a filler in foundry sand mixes is still a matter of discussion within the Industry and clearly, even though it would remove one dangerous constituent, its elimination from foundry practice would not be justified if it resulted in "burnt on" sand and more dressing shop dust. Silica flour can, and should, now be purchased and used moist so as to avoid dust in the sand mixing processes, but we still hope that steel founders will persist in their efforts to work without silica flour because we are certain that, provided a good strip could be achieved, the Industry would benefit from the absence of this material. This is a complicated matter which we do not propose to discuss in this report, but the British Steel Castings Research Association have been working on the subject and we have included their views in Appendix VI.

30. Powder washing was first referred to in the earlier Report[2] in discussion on the flux injected burner and the Linde burner[21] where it was shown that, although the method does not eliminate dust or fume produced by dressing, it does change the composition of the free silica to fayalite and so eliminates the free silica from the breathing zone. We think therefore that the method is useful in those cases where it can be applied conveniently and much of the experience which has been gained on the use of this method has been examined by the British Steel Castings Research Association and is summarised in Appendix VII.

31. Another method of hot fettling consists of the use of a compressed air jet on a carbon arc. This method, too, produces copious fumes as air is blown over an arc struck between a graphite electrode and the work. On the other hand, the method avoids the use of the pneumatic chisel although it is not suitable where there is a large amount of "burnt on" sand for the simple reason that the arc cannot be struck from the electrode to sand. Appendix VIII contains the observations of the British Steel Castings Research Association on this method of fettling.

The Control of Dust

32. After the more positive techniques of dust elimination have been applied to the limits of practicability, there will still remain in most steel foundries, heavy dust concentrations which will have to be controlled. We have therefore devoted a considerable amount of our time and energy to the examination and development of suitable methods of dust control for the varying circumstances of the industry.

33. The T piece is frequently used to clean moulds and the dust removed from the mould is blown into the atmosphere of the foundry. This is no longer necessary as the work can be done in conjunction with dust collecting equipment. Quite apart from the T piece, many moulds are cleaned by blowing the dust and sand off the surface with a compressed air pipe. We think this process undesirable and we hope that vacuum methods will be introduced. Certain moulds may offer specific difficulties but the solution will not be found until someone tries and we know that vacuum methods are in use in some foundries on some jobs. We think that their use should be extended.

34. It is often possible to reduce the dressing shop dust concentration by careful attention to the sequence of operations after casting. This is a matter of considerable importance and although no strict order of operations can be given, castings should always go through some form of mechanical blasting equipment before being given to fettlers. If they can also be annealed before the fettlers get them, this is all to the good.

35. Blasting equipment of various types can be used to de-core, to remove large quantities of sand, to remove some "burnt on" sand and to control the dust at the same time, and this form of cleaning should not be overlooked as a method of dust control in the dressing shop. One very good way of de-coring and removing large quantities of sand is by wet blasting after which shot blasting may be used to remove "burnt on" sand. Where wet blasting is not employed, castings should certainly be shot blasted before being given to the dressers. Obviously, a very high standard of maintenance is needed in all shot blast equipment if the dust cloud resulting from the process is to be properly controlled.

36. We have already advocated the use of vacuum methods as part of the process, but we also think that the vacuum cleaner offers the best method of sweeping both walls and floors. We know that mobile vacuum cleaners return the filtered air to the atmosphere of the room in which they work and so it may be that foundry cleaners should be fitted with suitable filters of the highest possible efficiency so as to reduce as far as practicable the amount of fine dust returned to the foundry atmosphere. Where vacuum cleaners are not used, walls and floors should be damped before sweeping, but we know that the vacuum method is in use in some foundries and we think that it should be extended as far as possible.

Dust Control by Wet Methods

37. Water may be used either to eliminate dust or to control it and a clear distinction should always be made between these two methods. If a process can be done wet or in suspension, there will be no dust and this is an elimination

technique. For instance, it has been shown by the British Cast Iron Research Association[22] that moulding sand is dust free if it contains about one half of its working moisture content and if the moisture is thoroughly milled into the sand. This use of water to eliminate the dust from the sand is an elimination technique and not a control method. When an airborne dust cloud has been allowed to form, efforts may then be made to control it by means of water sprays and this is a control method. A good deal of work has been done on the use of water, and water to which a wetting agent has been added, to reduce the surface tension, but the results have not been very promising and for all practical purposes it is probably true to say that the work has confirmed the view that it is impossible to control a dust cloud by means of water sprays once the cloud has been allowed to become airborne.

Local Exhaust Ventilation

38. The Dust in Steel Foundries Committee remarked in the earlier Report[2] that in the application of local exhaust ventilation to the steel foundry, they had concentrated especially on two tools because those tools appear to have received little attention in the past even though they undoubtedly contributed large amounts of dust to the dressing shop atmosphere. These two tools were the pneumatic chisel and the abrasive wheel and because it seemed to the Dust in Steel Foundries Committee that the more profitable line of approach would be to concentrate on light castings, they dealt only with that aspect of the matter. They added the comment that there appeared at the time to be no entirely satisfactory means of applying local exhaust ventilation to very heavy castings and suggested that these heavy castings might be more easily dealt with by other methods.

39. The work of the earlier Committee[2] resulted in (1) the production of a dressing bench fitted with a system of local exhaust ventilation, (2) a new ventilating system for pedestal grinders, (3) a variety of new systems for swing frame grinders, and (4) the use of powder washing and the air carbon arc torch, the fumes from which can be controlled by the normal methods of local exhaust ventilation.

40. Since the publication of the earlier Report[2] a large amount of research and development work has been done on the application of local exhaust ventilation to portable dressing tools. This work has resulted in (1) new dressing benches, (2) new systems for swing frame grinders, (3) the application of movable exhaust hoods, and (4) the low volume high velocity ventilating system.

We have already commented on the difficulty in controlling dust when stripping heavy castings and suggested that wet cleaning methods or blasting techniques when they can be applied may eliminate large amounts of dust associated with stripping, de-coring and the preliminary cleaning of castings before the dressers get them. The sequence of operations is of great importance. If the preliminary cleaning can be done by means of water, or by blasting, the dressers will receive relatively clean castings so that the new methods of dust control will not then be overloaded and will in consequence give far more satisfactory results.

At the present moment (omitting heavy stripping processes) one or other local exhaust system can be applied to every portable mechanical dressing shop

tool. A high standard of dust control has been attained in laboratory conditions and in practice examples of development are to be found working in foundry dressing shops. There are difficulties both in using the new systems in all the various conditions of different dressing shops and in getting foundrymen to accept them. We believe that there is in the industry a genuine desire to overcome these difficulties and because we think that with goodwill on all sides they can be overcome we take the view that the initial difficulties should not deter firms from installing this equipment nor should they deter them from making every effort to get such equipment to work successfully. Excluding for the moment heavy stripping and de-coring (for which we have suggested other methods) there will still be occasions when the local exhaust systems now available will give something less than complete control of the dust, but we think that every dresser should be provided with some form of local exhaust system and that everybody concerned should use these systems to the utmost of their practicability.

41. We propose, therefore, to summarise the large amount of work that has been done on so many aspects of protection against dust since the publication of the earlier Report[2]. We have no doubt that further work and more experience may well produce different methods, but we have no doubt either that suitable protective methods should be selected from the variety which is now available and applied by every steel foundry at once because dressers should not work the tools without the protection that is now available. We know that this is now a legal obligation under the Iron and Steel Foundries Regulations, 1953[23], but quite apart from this, we look for a sense of responsibility which will ensure that these new devices will be installed and worked to the highest possible standard by men and management together.

Knock-out

42. Many bodies are interested in conditions in foundries but we thought it desirable to avoid the duplication of research and development work as far as might be possible. In consequence, we have not concerned ourselves very closely with the knock-out problems because we arranged that this should be handled by the Joint Standing Committee on Conditions in Iron Foundries. The knock-out offers a series of problems because the nature of the process depends on the kind of work that has to be done. In general, however, the processes which together are known as knock-out processes can be divided into three main groups consisting of (1) heavy foundries, (2) light foundries, and (3) mechanised foundries. We know of only one attempt to apply local exhaust ventilation to heavy pit knock-out[24] and we do not think that this problem has yet been satisfactorily solved. The dust produced by the knocking out of light castings is much more easily controlled if the castings can be brought to one or more central knock-out points. The Technical Panel of the Foundry Atmospheres Committee which was set up by the British Cast Iron Research Association published[25] results of a careful examination of the different ways in which local exhaust ventilating plant could be applied to a mechanised knock-out (see Appendix IX). They concluded that the most efficient method is by the complete enclosure of the knock-out. This is no easy matter but there is no doubt that where it can be achieved it would provide the best solution to the problem, and for this reason we think it is worthy of consideration especially in the design of new plants. When the knock-out cannot be totally enclosed, and at the

moment this will be the largest proportion of the cases in ordinary practice, the Panel took the view that the next best method of applying local exhaust ventilation was by means of a side draught system which might, or might not, be assisted by a positive air movement to blow the dust towards the extraction hood. They did not regard down draught exhaust as being particularly efficient except in a very restricted number of cases and although they pointed out that the up draught system did extract the dust in the direction in which it was actually moving, they indicated that they did not like the system except in very special circumstances because the tendency was always for the operator to put his head into the rising stream of dust and air. We are informed that further work is in progress on dust control methods at knock-out operations.

43. Although the main project was handed over to the representatives of the iron founding industry, some work has been done on the matter by interested steel founders (see Appendix X). A description of a retractable hood which almost completely enclosed a knock-out was published[26] some years ago, and the method which was developed in Sweden has now been extended, a recent prototype being described in the discussion on a paper published at a British Steel Casting Research Association Conference[27]. Other work was also described during the same discussion[27]. At the same Conference[28] a paper was published by a member of the staff of the British Cast Iron Research Association which described the experimental results which had accrued from the work done on this problem by that Association.

The Dressing Bench

44. Light castings can be dressed on benches and the earliest attempts at dust control were restricted to the application of local exhaust ventilation to the dressing bench itself[2]. Work done some years ago showed that a bench in which the exhaust system was assisted by a positive air movement in the direction of the hood was more efficient than a simple down draught system[12, 29]. Since that time further adjustments have been made to the bench which have been concerned, not so much with the efficiency of the local exhaust ventilating system as with the difficulty of handling the work on the bench. This is probably just as important as the efficiency of dust control because, however good the dust control might be, the bench will not be used unless the work can be handled on it with comfort. More recently a new type of dressing bench has been designed and the whole of this work is discussed in more detail in Appendix XI.

The Pedestal Grinder

45. When it had been shown[12] that the local exhaust ventilating system normally applied in those days to pedestal grinders was inefficient, the British Steel Castings Research Association commenced a research and development project in an effort to provide improved dust control. The work was done on a 24″ × 2½″ wheel running at a peripheral velocity of 9,000 ft per minute[30]. The conventional hood was used and in the final design on the 24″ × 2½″ wheel the space between the hood and the wheel on each side was 1½″ while the top scraper was so adjusted as to leave a space of not less than ½″ between the scraper and the wheel face. A special work rest was used which was either provided with slots or fitted with rollers so that the ventilating air could flow through it when it was not obstructed by the casting being ground. Dust control

was achieved by the extraction of not less than 900 cu. ft. of air per minute at a water gauge of 0·8 inches when this was measured immediately behind the top opening of the hood. Appendix XII contains the report of the British Steel Castings Research Association on the system which is now in common use, and which can now be fitted to wheels of all sizes.

46. The British Cast Iron Research Association also developed a new form of dust control for pedestal grinders. In the first instance, a 14″ × 2½″ wheel running at 5,000 peripheral feet per minute was fitted with a system which became known as the external dust control system[58]. The dust was collected through three ducts, one placed above and one on each side of the wheel. Subsequently the system was extended to the 24″ × 2½″ wheel running at 9,000 peripheral feet per minute when a combined system operating at 5½″ of water gauge incorporated the internal and external systems[59]. The system can now be fitted to wheels of all sizes and is described in more detail in Appendix XIII. This system too is now in common use.

The Swing Frame Grinder

47. The earlier Committee[2] published a description of the first attempt to fit exhaust ventilation as an integral part of the swing frame grinder[32]. The work was then taken over by the British Steel Castings Research Association and an integral exhaust system was produced and shown to be effective[31] when extracting 900 cubic feet of air per minute at 3¾″ static water gauge from a 16″ dia. wheel operating at a peripheral speed of 9,000 feet per minute. This work is described in Appendix XIV.

48. The Research Association also examined booth extraction and finally suggested the combination of an integral exhaust system and a booth[31]. This work was done in order to provide an alternative to the integral system which some operatives thought might not be suitable in all circumstances. The combined system of booths and integral exhaust is described in Appendix XIV.

Movable Hoods

49. Recently an effort has been made to use movable exhaust hoods fitted to the ends of flexible pipes. For any local exhaust ventilating system there is a known limit to the distance between the source of dust and the hood face beyond which it is not efficient. In practice therefore the efficiency of movable hoods is determined by their adjustment and two factors are involved. On the one hand it may not be possible to bring the hood near enough to any particular operation to use at maximum efficiency and on the other even when it is possible the operator may not do so. In general by this means it is practicable to exhaust an increased volume of space within the vicinity of the work. The work which is in its early stages is of great interest and will be studied closely.

Low Volume High Velocity Exhaust System

50. Until recently there was no known method of controlling the dust produced by portable machines from castings which were too large or too heavy to be done on benches and the earlier Report[2] stated this as a fact. In consequence a member of our Committee, together with two development engineers from an industrial firm[33] commenced a series of research and development projects in an effort to provide some method of dust control for these machines. The work

resulted in a new conception of local exhaust ventilation and gave an original system which has become known as the "Low Volume High Velocity System". The name has arisen from the fact that the system uses small volumes of ventilating air moving at high velocity under high vacua. Small air volumes allow of the use of small diameter flexible ducts which can be affixed to and carried with portable tools, but the system must be applied very close to the point of origin of the dust and must be maintained in such a position to ensure effective dust control. The new system needs much smaller filtering equipment than is normally used and the low extraction volume does not appreciably affect general ventilation and extracts very little heat from the rooms in which it is installed.

51. The system was first used on percussive rock drills[34] in which the dust was extracted through a hollow drill by an air stream moving under a running vacuum of about ten inches of mercury at a velocity of 16,000 to 18,000 ft. per minute. It was then applied to foundry mechanical dressing tools and observations by the illumination and photographic techniques together with dust counts and samples taken with an Owens Jet Counter, a Konimeter and a Thermal Precipitator have shown that the method results in a high standard of dust control in laboratory conditions. A study has now been made of its use on many foundry mechanical dressing tools in working conditions and these applications are described below. In particular its application to portable grinding wheels and to pneumatic chisels has been the subject of extended trials in several steel foundries when the system has proved satisfactory for the grinders but not so satisfactory for the pneumatic chisels.

The Pneumatic Chisel

52. The system was first applied to a pneumatic chisel. A short flexible hose was fitted with a fish-tail nozzle provided with an opening $1\frac{1}{8}'' \times \frac{3}{16}''$ and held over the operator's hand in various positions above the cutting edge of the chisel. The nozzle controlled the dust from the top face of the chisel[35]. These nozzles did not, however, control the dust from the back face of the chisel and their efficiency varied with the position they occupied in relation to the cutting edge of the tool. The method was discarded by the original workers[35] because it was felt that the dust from the back of the chisel should be controlled and also in an effort to obtain a device which could be maintained in a fixed position with reference to the point of origin of the dust. This application of the system was however used in one dressing shop and some details of the work were published recently[36].

The original workers then went on to develop a hollow pneumatic chisel in which the dust was extracted through the chisel itself and through the pneumatic hammer[35]. The dust could be controlled by this method but after early experimental work it was discarded because of the mechanical difficulties involved in the hollow chisel. Finally an ordinary solid chisel was fitted with a rubber sleeve and the ventilating ducts were incorporated in the sleeve wall in such a manner that they were both above and below the cutting edge of the chisel. Pneumatic chisels are frequently used to cut flash but they are also used to strip heavy castings when large quantities of sand and dust are produced. In order to deal with the very heavy concentrations of dust a rubber conical extension duct was also fitted over the sleeve[39]. The experimental work done on pneumatic chisels is discussed in more detail in Appendix XV.

The application of this system to pneumatic chisels has not yet met with much general success in steel foundry conditions, although experimental and development work is still being done and there are a few instances (not all of them in the steel founding industry) where the method is now being used. Although good control of the dust has been obtained with chisels under laboratory conditions, this is difficult to achieve in all normal fettling shop conditions. In relatively straightforward work such as the cutting of flash there appears to be no insuperable difficulty and good dust control can be achieved. This type of work, however, in many dressing shops forms only a relatively small proportion of the fettling and with increasingly difficult conditions the systems become correspondingly difficult to apply. The exhaust duct must be placed close to the cutting edge of the chisel and this obscures the operator's view when working in confined spaces, e.g. cored cavities. When used over a glove the exhaust duct is not always close enough to give the dust control that the system is otherwise capable of, and when applied through the sleeve there are cavities so small that the chisel with its sleeve cannot be inserted. The efficiency of the system falls when the chisel is being moved about fairly rapidly on the surface of a casting during a "bumping up" operation, or during the removal of areas of "burnt-on" sand. The dust control may be improved in the latter case by fitting the extra conical duct, but this is an additional adjustment and the cone obscures the view of the operator.

The Portable Grinder

53. The low volume high velocity system was then fitted to the six-inch diameter portable grinder[35] through ports in a double wall which formed a peripheral duct of rectangular section in the wheel guard. At a later stage the system was redesigned to work through a much smaller wheel guard[42] and finally an extractor head was produced which will control the dust in the absence of a guard[39]. This head, which can be used with or without a guard, allows the maximum exposure of the wheel face. Finally, the head was found to collect sparks as well as dust and when grinding certain alloy steels these sparks were hot enough to obstruct the ducts and also to soften the hose. A spark trap was then designed to cool the sparks and the inlet ports were modified to meet this difficulty[40]. The whole of the work is discussed further in Appendix XVI.

Portable grinding wheels fitted with this exhaust system have proved satisfactory under foundry conditions and will probably be used on an increasing scale.

The Portable Surface Grinder

54. The low volume high velocity system was also applied to the portable surface grinder[38] or disc or cup grinder as it is sometimes called. The dust was extracted through a series of ports mounted in a circular duct which nearly surrounded the wheel. The latest modifications were published recently[39] and further details are given in Appendix XVII.

The Cone Wheel

55. Cone wheels are normally used on internal surfaces and in cavities so that hoods cannot be fitted. It has been shown, however,[41], that the dust from these wheels can be controlled by a new type of extractor head which fits just behind

the wheel and through which the low volume high velocity ventilating system is applied. Further details of the work appear in Appendix XVIII.

The Swing Frame Grinder

56. The method was then applied to a swing frame grinder[38] and later to a transverse swing frame grinder[39]. Finally, a new type of head was designed with certain modifications which were found useful in practice[41]. Details of the machines are given in Appendix XIX.

Respirators

57. We agree entirely with the earlier Committee[2] in that we cannot consider personal protection to be an ideal method, but we do think that it has a vital purpose and we consider that all operatives should wear the masks on which a good deal of energy has been spent in an attempt to make them more comfortable and more efficient. In particular we think that masks should always be used during the repair of ladles and converters in those operations during which dust from the refractories would otherwise be breathed.

The earlier Report[2] referred to a new type of dust respirator which has been sponsored by the British Steel Founders' Association and also indicated some preliminary experimental work on a respirator which was designed to provide the wearer with a fresh air supply[43]. Since that time the British Steel Castings Research Association has done a good deal of work on this type of mask. Two member firms of the Association have described modifications made to existing respirators to supply fresh air to the wearer. This makes it easier to breathe and also makes the mask more comfortable to wear. A description of the recent development is given in Appendix XX.

The Collection of Dust

58. Much of our work has of necessity been devoted to the control of dust because when we started there were many tools in the foundry on which it was not possible to control the dust in certain circumstances. Once the necessary work was in hand on this aspect of the matter, we turned our attention to the efficiency of dust collectors and we are indebted to the British Steel Castings Research Association who have gathered together a good deal of information on this rather important aspect of the matter. The efficiency of the various types of dust collectors varies over a wide range, the capital cost of installation and the power consumption and running cost of the various types also vary widely so that it is a matter of some importance to foundrymen that they should have information on which they can select the kind of dust collector that they need. Some of this information was published recently[44] and Appendix XXI offers a more detailed description of the whole matter. Dust collectors should be so sited, worked and emptied that neither contaminated air nor dust enters workrooms.

MISCELLANEOUS MATTERS

Noise

59. The subject of noise in foundries has not received much detailed attention. Some steel fettling operations are associated with high noise levels and we are glad to know that the British Steel Castings Research Association is now

devoting a lot of attention to this subject. The new fettling bench developed by the Association which is described in Appendix XI incorporates features which produce a substantial level of noise reduction when it is used for the dressing of castings with penumatic chisels.

X-Ray Surveys

60. The earlier Report[2] made reference to a mobile radiography unit which was set up by the British Steel Founders' Association. This unit which is still in use has made systematic visits to steel foundries all over England, Scotland and Wales so that men can be examined at regular intervals. After nine tours had been completed the Association decided to examine the mass of information available, and the medical advisers of the British Steel Founders' Association have now drafted a first report on their preliminary examination and assessment of that information. We are indebted to the doctors who have performed a very useful service to the industry and to the British Steel Founders' Association for a sight of this report which we have decided to publish as Appendix I. There are differences of opinion in the Committee on the statistical conclusions in the report, but we have no doubt that the facts and figures contained in this report will be examined in due course and set into the context of all the other evidence on pneumoconiosis. Meantime, we think that all the information that can be found should be set before the industry and so the report (Appendix I) is published without further comment.

Toxicity of Dust

61. The British Steel Castings Research Association has continued to sponsor work at the University of Reading in which animals have been subjected to silica and various mixed dusts to determine factors bearing on the formation of fibrous lung tissue. These animal experiments have been supplemented by a study of the reactions between silicic acid and tissue constituents which have thrown some light on the origin of silicosis. Some of this work has already been published[16, 17, 45, 46, 63–72].

Fumes from Furnaces

62. Many furnaces emit large amounts of fume at certain times during the process and this volume of fume will be increased considerably if oxygen lancing is used. Where efforts have been made to control these fumes, it has been normal practice to fit hoods, but further work is in hand and much more work is still needed to determine the most satisfactory way to control this fume. The Joint Standing Committee on Safety, Health and Welfare Conditions in Non-Ferrous Foundries is also dealing with this matter[47], although on much smaller furnaces than are normally used in steel foundries. We have no doubt that if these fumes could be controlled, there would often be a much lower dust concentration in the steel foundry.

Clean Air Legislation

63. The Clean Air Legislation does not directly affect us under our terms of reference. We are, however, bearing in mind the implications of this legislation so that any recommendations which may be made with regard to matters inside the foundry shall not run counter to the requirements of clean air outside.

Carbon Monoxide

64. The Joint Standing Committee on Conditions in Iron Foundries has directed a good deal of attention to the problems associated with the production of carbon monoxide by the various foundry processes[3, 48, 49] and so we have left this work to that Committee in order to avoid duplication of effort. We have included a synopsis of the work with the conclusions in Appendices XXII and XXIII because we think that the results of this work are worthy of the attention of steel founders.

Core Binders

65. We have left this matter also to the Joint Standing Committee on Conditions in Iron Foundries and a recent publication[3] contains the results of the deliberations of that Committee. The subject is highly complicated and the Iron Committee has not yet been able to reach final conclusions but we have included a summary of their work and their recommendations in Appendices XXIV and XXV so that the steel founding industry might be informed as to the present position.

Shell Moulding

66. We understand that this subject has been discussed in some detail by the Joint Standing Committee on Conditions in Iron Foundries and also by the Joint Standing Committee on Safety, Health and Welfare Conditions in Non-Ferrous Foundries. We thought that these other branches of the founding industry were more immediately concerned with the process than we were in steel founding and so we agreed to await the results of their discussions. A statement has been made in the Report of the latter Committee[47] and for ease of reference we have included this as Appendix XXVI so that the steel founding industry might be fully informed.

The Carbon Dioxide Process

67. We have given this process some consideration but once again the main work on the matter has been done by the Joint Standing Committees on Iron and Non-Ferrous Founding and the first public statement has been made by the Joint Standing Committee on Safety, Health and Welfare Conditions in Non-Ferrous Foundries. It is clear that this Committee would like further information about the process and we cannot but agree with them. We think, however, that their observations[47] will be of much interest to steel founders and in consequence we have reproduced them as Appendix XXVII.

HEALTH

Pneumoconiosis

68. In the Second Report of the Dust in Steel Foundries Committee (1951)[2] a short summary was given of the results of a comprehensive investigation by A. I. G. McLaughlin and others into the pulmonary industrial diseases of iron and steel foundry workers. It was pointed out that fettlers of steel castings were exposed to a serious risk of silicosis often accompanied by tuberculosis and that workers in steel fettling shops were liable to develop more severe X-ray abnormalities than in any other foundry occupation. Varying incidences of X-ray abnormality occurred in other steel foundry occupational categories.

These abnormalities are clearly related to the dust inhaled during work and at that time the dust from steel fettling was not controlled. It was shown that there had been a yearly increase (up to 1947) in the number of certificates granted to steel fettlers by the Silicosis and Asbestosis Medical Board in respect of death or disablement due to silicosis.

By contrast it was shown that there had not been a comparable increase in the deaths or disablement from similar causes in shot and sand blasters, and this fact was attributed to the Regulations requiring dust control measures for blasting processes. The risk of silicosis or pneumoconiosis to workers in steel moulding shops is less than that of the fettling shops.

69. In 1948, the Silicosis and Asbestosis Medical Board was incorporated into the Ministry of National Insurance (later combined with the Ministry of Pensions) and by agreement with that Ministry, the Medical Branch of the Factory Inspectorate has been able to examine the working histories of claimants accepted for pneumoconiosis benefit.

In addition, the Registrar General supplies the Factory Inspectorate with copies of all death certificates in which fibrosis of the lung, including pneumoconiosis, is recorded, while the Registrar General for Scotland provides similar information for that country. For many years, a classification of these death certificates has been published in the Annual Reports of the Chief Inspector of Factories. In 1957, it was decided to attempt to identify further certain industries, while for purposes of comparison with earlier years, this new classification was projected back to 1953.

These two sources of information have together with additional information in many cases from enquiries into the working histories of the deceased, been further examined and provide the material for the ensuing two paragraphs.

70. In Table I are analysed for each of the years 1953–1958 death certificates of 151 steel foundrymen in which the presence of pneumoconiosis was recorded. This total was arrived at following further examination, when 23 of the 174 cases included for that period in the Annual Reports of the Chief Inspector of Factories have been excluded in this analysis. Working histories were available for 126 cases, and for the remaining 25 cases the only evidence of a steel foundry employment was that on a death certificate.

TABLE I

**Death certificates recording pneumoconiosis*

	England and Wales						Scotland
	1953	1954	1955	1956	1957	1958	1953–1958
Occupational history available	6	12	18	26	11	18	35
Death certificate evidence only	4	2	4	2	3	3	7

* In a few cases, pneumoconiosis was not recorded as the initial pathological cause.

An analysis of these death certificates and working histories shows clearly that steel fettling and dressing was the principal occupation. This occupation appears to be the significant one in 112 of the total of 151 deaths analysed, thus supporting the investigation of McLaughlin and others referred to in paragraph 68.

Other steel foundry occupations, hy comparison, are mentioned relatively infrequently. Included among them are 12 sand or shot hlasters and four steel moulders, the remainder heing mixed or general foundry occupations.

71. Figures for newly diagnosed cases of pneumoconiosis among steel foundry workers during the years 1953–1956 are given in Table II. In analysing the occupations of these men, it was found that in many instances the history is complicated hy possibly significant employment in some other industry. In consequence, the total is suh-divided into three categories—those in whom the only significant employment in relation to pneumoconiosis was in steel foundries, those with mixed foundry employment and, lastly, a considerable group with exposure to a pneumoconiosis risk in steel foundries, and elsewhere, mainly in coal mines.

TABLE II*

Newly Certified Cases of Pneumoconiosis in Steel Foundry Workers (Great Britain) 1953–1956

Year	Significant Steel Foundry Employment only	Mixed Steel and other Foundry Employment	Mixed Steel Foundry and other non-Foundry Employment	Total
1953	56	7	19	82
1954	62	19	29	110
1955	71	10	19	100
1956	64	13	21	98

72. Tahle III analyses hy occupation, the cases with significant exposure in steel foundries only. An analysis of the other two groups is not given as it is not possible to determine, from the information availahle, the relative importance of the steel foundry and other exposures.

TABLE III*

Occupation	1953	1954	1955	1956	Total
Steel fettlers and dressers	40	36	49	37	162
Steel grinders	1	2	1	3	7
Burners and welders	5	4	3	9	21
Sand and shot blasters	2	—	2	3	7
Steel moulders	3	10	6	5	24
Other, or not classifiable	5	10	10	7	32
Total	56	62	71	64	253

* This information was available for the years 1953–1956 only.

It will be seen that as in the evidence derived from death certificates, the numbers of new cases in steel moulders are low as compared with those in steel fettlers and dressers. A feature of interest is that 21 burners or welders (oxy-acetylene and electric arc) in the four-year period were diagnosed as suffering from pneumoconiosis. Many of the abnormal shadows in welders' X-ray films of the chest are caused by deposits of iron oxide which usually cause no pulmonary fibrosis, but it has been shown that when welders work in foundry fettling shops they are exposed to the dust of free silica in the general atmosphere and may develop a mixed dust fibrosis which is a modified form of silicosis.

No accurate employment figures on the various trades at risk are available, but, in general, it can be stated that 23% to 28% of all steel foundry personnel are employed in fettling shops; and 35% to 40% in moulding and coremaking shops, of whom one-third are engaged on actual moulding and coremaking. The number of men employed on blasting is seldom more than 2% of the total employed in the industry. The total numbers employed in the steel founding industry are given below:

Year	*Number employed*
1950	18,869
1951	19,084
1952	20,814
1953	20,417
1954	19,650
1955	19,900
1956	20,010
1957	20,480
1958	19,460

The figures given in Table III are almost certainly an underestimate unless it be assumed that in none of the cases in columns 2 and 3 of Table II was dust exposure in steel foundries significant. In assessing, however, the significance of the totals as shown, account must be taken of the influence of "awareness" which once the occurrence of a disease is recognised, tends initially to inflate the numbers diagnosed, as the "back-log" is identified. The survey undertaken by the British Steel Founders' Association has no doubt helped to increase the number of cases appearing before the Pneumoconiosis Panels, although the main "back-log" of that Survey was prior to 1953.

Some steel foundry firms have set up their own X-ray plant at the factories, whilst many others make use of the facilities for periodical X-ray examinations provided by the British Steel Founders' Association. The Committee is of the opinion that such examinations together with general medical examinations should be instituted by all foundries combined with determination of the chemical composition, concentration and particle size distribution of the airborne dust.

Causes of Death in Steel Foundry Workers

73. A long-term inquiry into the causes of death in iron and steel foundrymen on whom an autopsy had been performed has been undertaken by a former member of the Committee (Dr. A. I. G. McLaughlin) who, with Dr. H. E.

Harding, has published the results of pathological examination of the lungs of 85 cases and compared them with a previously published series of 64 cases[62]. These authors point out that autopsies are obtained in nearly all cases in which pneumoconiosis is suspected and only in a proportion where it is not. The findings therefore cannot be used as evidence of the incidence of pneumoconiosis in foundry workers. From steel foundries there were 54 cases made up of 16 dressers, 13 grinders, 5 shot blasters, 5 welders and cutters, 5 furnace workers (ladlers and labourers), 2 furnace bricklayers, 2 crane drivers, 4 foundry labourers, 1 pattern maker and 1 stone racer.* These occupational categories cover approximately 60% of the steel foundry personnel. The commonest lesions found in the lungs at autopsy were pneumoconiosis (silicosis and/or mixed dust fibrosis) usually associated with emphysema, tuberculosis, cancer of the lung, bronchitis, lobar pneumonia, bronchopneumonia and coronary thrombosis. In many cases two or more of these conditions were found together, as for example pneumoconiosis and tuberculosis. Again in those cases with pneumoconiosis the primary cause of death might be different, e.g. purulent bronchitis, pneumonia, haemoptysis, carcinoma of the bronchus, coronary thrombosis or accident.

Pneumoconiosis (silicosis and/or mixed dust fibrosis) was found in varying degrees of severity and in a number of cases was not the actual cause of death. It was a factor in the death of 11 out of 16 steel dressers; in a further 2 it was a doubtful factor and in 3 it was not a factor. One of these was a man of 49 years of age who had been a steel dresser in the same fettling shop for 36 years. He died from cancer of the lung, but his lungs showed no evidence of silicosis or mixed dust fibrosis. The case illustrates the factor of individual susceptibility because in 9 other men from the same dressing shop silocisis was found to be present at autopsy.

Of 13 steel grinders pneumoconiosis was a factor in the death of 7; in 2 others it was doubtful and in 4 it was not a factor. It is interesting that there were no steel moulders in the series of 54 cases. In the 5 shot and sand blasters, pneumoconiosis was a factor in the death of 4 and not a factor in 1. The average age at death of these 5 men was 66 years compared with 48 years (21 cases) in a 1950 series. The average age at death of the steel fettlers was 52·4 years and of the steel grinders it was 59 years.

Pneumoconiosis was found in 3 of the 5 welders and cutters, though it was not a factor in the death of any of them; 4 of them died suddenly, one from coronary thrombosis, one from pulmonary embolus, one from sudden heart failure and the fourth died as the result of a cycling accident. In the cases of the furnace ladlers and labourers in which pneumoconiosis was present, it was only a doubtful factor in their deaths. Both furnace bricklayers had pneumoconiosis; in one case it was recorded as a factor in the cause of death, in the other as a doubtful factor. In two of the four foundry labourers slight pneumoconiosis was found but it was not a factor in the deaths. Two of this group died from cancer of the lung and two from coronary thrombosis. Both the crane drivers had slight pneumoconiosis but died from other causes (coronary thrombosis or accident). The pattern maker also had slight pneumoconiosis but died from another cause.

The main causes of death in this group apart from pneumoconiosis were

* Stone racer is not a foundry occupation.

tuberculosis, cancer of the lung, pneumonia and coronary thrombosis. Comparison with the earlier series in 1950 showed that there were fewer cases of tuberculosis but more of cancer of the lung. It is not known whether the increase of the latter disease is partly occupational in origin or whether it is part of the increase found in the general population.

Evidence was produced that the X-ray changes in the lung fields of these workers are not due solely to siderosis (deposits of iron pigment in the lungs) as has been claimed by some investigators but also to silicosis and mixed dust fibrosis. Any foundry worker is liable to contract dust fibrosis, but the risk varies widely, being greatest in the foundry cleaning room workers, particularly in steel fettlers or dressers.

Chronic Bronchitis

74. Many workers suffering from pneumoconiosis also have chronic bronchitis often associated with emphysema and it has long been thought by many investigators that in some cases at least occupational factors have played a part. As long ago as 1915, E. L. Collis, at that time H.M. Medical Inspector of Factories, drew attention to the association between the two conditions, and in 1923 E. L. Middleton (also of the Medical Branch of the Factory Inspectorate and an original member of the Dust in Steel Foundries Committee) considered that three types of pulmonary disease were associated with the dust from the cleaning of castings and metal grinding, namely pulmonary fibrosis, bronchial catarrh and bronchitis. Foundry workers usually work and live in industrial towns and it is noteworthy that many inhabitants of such towns (and not only foundry employees) suffer from chronic bronchitis and emphysema as a result of air pollution and other causes. It is therefore difficult to decide in individual cases of bronchitis how far "town" or "trade" have been responsible for the development of the disease.

Other causes of Ill-health

75. No precise evidence is available about other causes of ill-health amongst steel foundry workers and it would be desirable to have more factual data about them. The number of doctors associated with steel foundries is gradually increasing and they may be able to collect and analyse information about the general causes of illness in such factories. Some maladies such as pneumonia and rheumatism might have an occupational factor in their causation. Until this information is collected and collated over a period of years we shall not be in a position to offer advice about the prevention of such illnesses. A good deal more clinical data is desirable and we would welcome publication of any results which doctors may have.

ACCIDENT PREVENTION

Analysis of Accidents

76. Most of this report is devoted to the prevention of industrial diseases in steel foundries by the elimination, suppression or control of dust and fumes, but the equally important problem of accident prevention has not been neglected.

All the legally reportable accidents* which have occurred in steel foundries during the years 1953–1956 have been classified and the results of this analysis are shown in Appendix XXVIII, Tables I to IV.

From Table I it will be seen that after a substantial reduction in 1954 the total has since remained practically constant and this suggests that the time has come for a concerted effort by all concerned to bring about a further reduction.

A study of these Tables together with the accident reports has indicated several different methods of tackling the problem as described below.

Good Housekeeping

77. It will also be noted from Table I that the relative sizes of the main causation groups remain substantially constant and a most important feature revealed by this Table is that over 50% of the accidents are contained in three groups, namely No. 7 Handling Materials, No. 8 Falling Articles and No. 9 Stepping On; Striking Against. A study of the individual accident reports reveals that a prominent contributory factor in a large proportion of the accidents in these groups is bad housekeeping, the injured person having slipped or tripped over some irregularity in a badly-maintained floor or over some tool or other piece of equipment left lying about in a dangerous position.

It is abundantly clear that this type of accident could be substantially reduced by more careful attention to the conditions of floors and to the proper storing of tools and equipment particularly when only temporarily out of use, as this is just the time when they are liable to be left lying about the working area and even obstructing gangways.

Foot Injuries

78. Table II shows the distribution of accidents resulting in injuries to feet and it is at once apparent that falling articles account for a very substantial proportion of the total. Many of these are caused by the injured person dropping an article, due to his tripping or slipping as described above; that is to say bad housekeeping is often a contributory if not the main factor.

Many of these accidents would either have been prevented altogether or at least been greatly reduced in severity if the injured person had been wearing safety boots.

Considerable efforts have been made during recent years to get foundrymen to wear this type of footwear and most firms now supply it at cost price. The slight but steady reductions in this type of accident during the four years may be an indication that the propaganda is beginning to have some effect, but the fact that foot injuries are still nearly 25% of the total indicates that there is still room for much greater improvement.

Eye Injuries

79. A detailed analysis of the accidents resulting in eye injuries is given in Table IV and shows that during the four years covered by the analysis there has been a steady and substantial decline in this type of injury. This is almost certainly due to the greatly increased use of goggles and eye shields resulting

*Accidents which prevent a person for more than three days from earning full wages at the work at which he was employed, must be reported to H.M. District Inspector of Factories.

from the Regulations requiring eye protection to be provided and worn for certain foundry processes.

A study of the individual accident reports indicates that most firms now provide eye protection and the majority of cases now being reported are due to the fact that the injured person was not wearing his goggles or eye shield at the time. It would appear that with stricter supervision and more persuasion this type of accident could be almost eliminated.

It is clear that most of the difficulties originally experienced in getting the men to wear some form of eye protection have now been overcome by some firms and this is mainly due to the fact that more types of goggles and eye shields are now being provided, and it is now more generally realised that correct fitting and comfort are important factors. Because of this it is often desirable for a selection of different types to be made available, since what suits one man will not necessarily suit another.

In the past many cases have occurred where a man has been injured by a particle from an adjoining working position when he has temporarily removed his own goggles, while numerous cases have occurred to passers-by in adjoining gangways. Much has been done to reduce this type of accident by the provision of suitable screens between adjoining working positions and also between working positions and gangways.

It is interesting to note the very low proportion of molten metal injuries compared with other branches of the foundry industry. This would appear to be due to the different methods of working, e.g. in the steel industry there is much less handling of small quantities of metal by different individuals and consequently far fewer persons are exposed to the risk.

Strains

80. There has been a slight but consistent reduction in the accidents which occur during the handling of material (Group 7) during the period under review, but the main feature in this group is that about 50% of the total every year result in strains, many of them severe.

It has already been pointed out that bad housekeeping is often a contributory factor in this type of accident, since a man may be carrying a load which is well within his normal capabilities, but if he happens to slip or trip over some obstruction a severe strain can easily result.

On the other hand many strains can be attributed to attempts to lift weights which are too heavy or awkward in shape.

It would appear that there is a need for wider instruction in correct methods of manual weight lifting, particularly among the younger generation; the older men often require to be warned to recognise the limitation imposed by increasing age.

The increasing application of mechanical handling equipment may help to reduce this type of accident.

Sepsis

81. When accidents result in cuts or abrasions of the skin the injury may subsequently turn septic; in many of these cases the original injury was only comparatively trivial and the injured person did not think it necessary to

obtain proper first-aid treatment; it cannot be too greatly stressed that proper treatment should be applied however trivial the injury.

Power Driven Machinery (excluding Hoisting Appliances)

82. The accidents due to power driven machinery have shown a steady decline over the period under review except for the last year, when a slight increase occurred which it is hoped will prove only temporary. The total of 68 accidents represents only about 5½% of the total for 1956, which compares very favourably with many other industries.

There is, however, room for further improvement, particularly in the reduction of accidents caused by abrasive wheels which account for nearly half of the total. Sand mixers and moulding machines share the second place and between them account for about a quarter of the total. These machines are difficult to safeguard, but the problem could be considerably simplified if more consideration were given to this important requirement in the design stage.

Hoisting Appliances

83. The accidents in this group after a substantial reduction of the 1953 total in 1954 and 1955 have unfortunately undergone a considerable increase in 1956. Again it is to be hoped that this is only temporary.

The great majority of accidents in this group are not due to any defect or failure in the machine or tackle, but to errors of judgment and carelessness on the part of slingers and crane drivers.

For example, of the 84 accidents in this group in 1955, no fewer than 71 came within the category of slinging accidents and were made up as follows:

Slipping or falling load	17
Struck by moving load (or slings)	11
Traps while handling load (or tackle)	35
Others	8
	71

The remedy in these cases should be self-evident and the figures may be left to speak for themselves.

Summary of Conclusions

84. The main point brought out by the accident statistics is that the yearly totals could be very substantially reduced by a determined attack on the principal causation groups and the most promising lines of action would appear to be:

(1) a higher standard of housekeeping, especially with regard to the provision and maintenance of better floors and gangways, with particular attention to obstructions both permanent and temporary on such floors and gangways;

(2) wider provision of suitable protective clothing and other protective devices;

(3) the proper care and use of such equipment by workpeople;

(4) early first-aid treatment for all injuries;

(5) better instruction and supervision in safe methods and practices in manual weight lifting and also in the handling of loads by cranes and other hoisting appliances.

For a campaign of this nature to be successful, two things are essential:

(a) there must be really keen interest and determination to succeed on the part of the management, and

(b) this must be supported by equally keen interest and the fullest co-operation on the part of the workmen.

It is suggested that this co-operation can often be best achieved by means of a Safety Committee, particularly where management and employees are equally and fully represented. It is, of course, true that many firms already have such Committees, but we are convinced that there is much new ground to be broken in this respect and some of the existing Committees could possibly do with some rejuvenation.

We were particularly glad to note that during 1955 the British Steel Founders' Association formed its own Accident Prevention Committee and it is hoped that this will stimulate interest and activity throughout the industry.

(Signed) H. WOODS (*Chairman*)
ROBERT BARBER
W. D. BUCHANAN
F. BULLOCK
J. GARDNER
T. JONES
ARTHUR LEVESLEY
F. N. LLOYD
J. G. McINTOSH
J. OWEN
FRANK ROWE
R. J. SARJANT
DUNCAN SCOTT
A. H. SULLY
J. H. WIGGLESWORTH
W. B. LAWRIE (*Secretary*)

APPENDIX I

Radiographic Examination of Steel Foundry Personnel

British Steel Founders' Association

As an Appendix to the Second (1951) Report of the former Dust in Steel Foundries Committee[2], there was published an account of the introduction, purpose and equipment of a Mobile Radiography Service, set up by the British Steel Founders' Association, as part of its programme for the minimisation of the pneumoconiosis hazard in steel foundries.

Twelve tours of the Mobile X-ray Unit have now been completed, in the course of which over 72,000 full-sized plates of the chests of steel foundry workers employed by B.S.F.A. Members, have been taken. The precise number of those possibly at hazard is not known, but more than 7,500 of those employed by Members of the British Steel Founders' Association have been examined at least once, and of a considerable proportion of these, something of the order of five to seven plates have been taken during the operation of the scheme.

The original intention of this scheme was to enable incipient lung changes to be diagnosed at an early stage, thus enabling the workman affected to seek clinical examination, and advice from his own doctor, as to how best to safeguard his health. It is emphasised that this was the limit of the original intention, and, therefore, that no investigation of the incidence of pneumoconiosis (silicosis) in the industry was contemplated.

After the cost of the scheme to Members of the B.S.F.A. had amounted to some £50,000, however, it was decided that, if the mass of material available were examined by properly qualified experts, it might be possible (*a*) to obtain some idea of the rate of onset of new cases of silicosis, and (*b*) to form some assessment of the rate of progress of the disease. The experts in this field who were appointed were Dr. L. G. Blair, F.R.C.P., F.F.R., D.M.R.E., and Dr. A. Lisle Punch, M.B., B.S., M.R.C.P. They spent some eighteen months examining the material, with the collaboration of the Works Medical Officers of the various foundries who are Members of the British Steel Founders' Association, and have prepared the following report which the B.S.F.A. now makes available.

B.S.F.A. Scheme for the Radiographic Examination of Steel Foundry Personnel

REPORT by
A. Lisle Punch, M.B., B.S., M.R.C.P. and L. G. Blair, F.R.C.P., F.F.R., D.M.R.E., on certain radiographic and clinical material accumulated during the first five years of the scheme.

A. INTRODUCTORY

In 1950 a scheme was introduced by the British Steel Founders' Association whereby a portable X-ray unit should tour the country X-raying the chests

of workers in steel foundries. All the foundries who were members of the British Steel Founders' Association were offered this service and 46 accepted it in the first instance. Five of these withdrew from the scheme subsequently, having set up schemes of their own of equal merit, 41 remaining in the scheme. The primary object of the scheme was that the attention of the Works Medical Officer, and, through him, the employees' own Medical Advisor, could be drawn to any signs of abnormal visceral conditions (see also paragraph (c) in Section E below).

In the first place, the tours were made at six-monthly intervals and later at yearly intervals.

All the films were reported on by Dr. Blair, who divided them broadly into two groups, the normals and the abnormals, the latter being communicated to the Medical Officers of the foundries concerned. The abnormals consisted of those showing nodulation, and also a considerable number showing other abnormalities such as tuberculosis, bronchectasis, carcinoma of the lung, sarcoidosis, etc. By the end of 1955 a great mass of radiological data had been obtained and it was felt that, although the scheme was never intended to be a research project, the time had arrived when an attempt should be made to analyse the results, and Dr. A. L. Punch was invited to co-operate in the clinical and occupational aspects of the problem.

It was hoped that, with the co-operation of the Medical Officers of the various foundries, it would be possible to form worthwhile conclusions on the following points:

(1) a fairly accurate estimate of the incidence of pneumoconiosis in the U.K. Founding Industry as a whole;

(2) the relationship between the disease and the different occupations followed in the foundries;

(3) the number of new cases that had developed in recent years;

(4) the progress of the disease in recent years both in those who have remained at the work in which they contracted it and in those who have changed their occupation; and

(5) the severity of the symptoms and degree of disablement at the different stages of the disease.

B. SELECTION OF CASES FOR X-RAY EXAMINATION

No precise information as to the method of selection of cases for X-ray has been supplied, and although this may have differed somewhat as from foundry to foundry, it can be assumed that in certain cases it was mainly those considered to be exposed to the greatest risk who were chosen, although the scheme is entirely voluntary and practice varies, so that the percentage incidence of pneumoconiosis of all those employed in the industry can be assumed to be considerably less than in those who were X-rayed.

C. RADIOLOGICAL ASPECTS OF THE SURVEY

The first step that was taken in the investigation was for us to review all the abnormal films and extract from them all those which we both agreed showed definite nodulation. Careful note was made of any change that took place in the pictures of each man over the period 1950–1955, such as coarsening of the

nodulation, development of massive shadows, and evidence of super-added tuberculous infection. No attempt was made to differentiate the radiological appearances of siderosis, from those of silicosis, as in our opinion this cannot always be done with any degree of accuracy. The differential diagnosis can only be made by reference to the man's occupation, and not always then.

D. METHOD OF COLLECTING THE REQUIRED INFORMATION

In order to obtain the required information a questionnaire, on printed forms prepared by the B.S.F.A. on our advice, was sent to the Medical Officers of each foundry, together with a list of the men whose X-ray pictures showed nodulation. In addition to answering the questions relating to the occupational history, age, personal medical history, etc., the Medical Officers were asked wherever possible to examine physically the men and record their findings on the cards.

The response to these questionnaires was slow and by May, 1957 only 10 out of the 41 foundries had replied.

Further representations were therefore made to the remaining firms with rather better results, though most of these stated that, owing to lack of co-operation on the part of the workers or other reasons, they would be unable to supply the clinical information for which they had been asked. As it was in the interests of all concerned that the survey should not drag on indefinitely, it was decided that it should be assumed that all the available information would have been received by the end of October, 1957.

It is on this assumption that this report has been based. On that date, 25 of the 41 foundries had replied to the questionnaire. The remaining 16 had either expressed their inability to co-operate or had sent information inadequate to be of any value, or had not replied at all.

Since the end of October, 4 other foundries have returned the questionnaire. These include some 80 cases of pneumoconiosis, which are not included in the present report.

E. STATISTICAL ANALYSIS

1. NUMBER OF MEN EXAMINED

(a) The number of men actually examined is not known precisely but the minimum cannot be less than the total of the largest number, firm by firm, examined tour by tour. This number, in respect of the firms covered by the Survey, cannot be less than 6,540. The total number of foundry workers employed by the firms covered by the Survey is (approximately) 8,550; so that, the sample is representative of 76·5% of the foundry employees of the firms covered.

(b) The total number of foundry workers employed by firms which are members of the B.S.F.A. is (approximately) 15,000; so that, the sample represents about 57% of the total employment of foundry workers by B.S.F.A. member firms.

(c) It must be borne in mind that the scheme is entirely voluntary and that a number of firms only submit for examination those employees who are believed to be especially at risk. Not all employees who are offered a chance are willing to be X-rayed. The consequence is that, statistically, the percentage of "abnormals" is arbitrarily enhanced.

2. RESULTS OF THE SURVEY

(a) *Identified Silicotics*

These fall into two classes.

(1) Back-log, and (2) New cases.

(1) *The Back-log* has produced 336
identified silicotics, or of the total examined . 5·1%

(2) New Cases of Silicosis amount to only 17
or
of the total examined . . . . . . 0·3%

(By back-log cases is meant cases in which nodulation was detected the first time the man was X-rayed. New cases are those in which the first film was clear, but nodulation appeared during the period of the survey).

(b) *Diminution of back-log identification year by year as scheme proceeds*

At the outset, the number of back-log cases, identified for the first time, was large, but the figure fell rapidly during the first three years.

The numbers identified year by year were as follows:

	No.	*Approximate % of those examined in that year*
1950	197	6·4
1951	68	1·9
1952	12	0·29
1953	26	0·54
1954	10	0·21
1955	20	0·38
1956	3	—
	336	5·1

The percentage figures shown are related for the years 1950/51, in each of which there were two tours, to the average figure for the two tours. For the remaining years they are related to the actual number examined in that year, in each of which there was only one tour. No percentage is given in respect of 1956, since the whole of the plates for this year have not yet been finally examined.

(c) *Degree of disability (back-log)*

We have taken the response to the exercise tolerance test as a measure of the degree of any disability present. Dyspnoea is the most constant and reliable symptom of pneumoconiosis and often the only symptom.

In 107 of these cases it has been impossible to determine the degree of disability, owing to lack of clinical information. Eighteen of the men have died since being identified as silicotics, during the course of the scheme, but only in four cases is the cause of death known: *in none of them is silicosis given as the cause.*

The distribution of the back-log according to degree of disability is as follows:

Severe	24
Slight	78
None	109
Not known	107
Deceased	18
	336

It will be noted that in only 24 out of 211 cases which it was possible to examine clinically, was there any serious disability. In a number of tbese there was, in addition to silicosis, some complication such as bronchitis, hypertension, etc., present which at least partly was responsible for the shortness of breath.

(*d*) *Foundry occupations* (*back-log*)

The heaviest burden of back-log cases is found, as might be expected, amongst fettlers and dressers. Moulders provide a much smaller number, to fall into second place. The actual figures are as follows:

Fettlers and Dressers	220
Moulders	36
Welders and Acetylene Burners, etc.	11
Sand and Shot Blasters	9
Crane Drivers	7
Furnacemen	8
Others	45
	336

The group labelled "others" is interesting, as amongst these were occupations not usually considered liable to give rise to pneumoconiosis. These 45 are worthy of a more detailed investigation.

It will be observed that 11 cases of welders have been classified as suffering from silicosis, though normally nodulation in such workers is due to iron staining (siderosis). It is not always easy to differentiate these two conditions radiologically, though sometimes the pattern of the nodulation is more suggestive of one or the other of them. In these 11 cases the film was more suggestive of silicosis than siderosis and moreover the men bad all been working as welders in fettling shops. For these reasons the balance of probability appeared to be in favour of silicosis.

(*e*) *Period of exposure prior to identification of the disease*

The period for which a man has been exposed to the hazard of silicosis is by no means easy to estimate. For example, a welder may be working

in a fettling shop for the greater part of his working life, but whether this is so or not, can only be determined with certainty by direct individual enquiry in each case. This has not been possible and the following table of average periods of exposure, occupation by occupation is based upon the best estimates that can be made in the light of what is known of each man's industrial history.

Periods of Exposure

Prior to First Observation of Abnormality

	Inadequate Information	Years of Ex. 10–15	Years of Ex. 16–20	Years of Ex. 21–25	Years of Ex. 26–30	Years of Ex. 31–35	Years of Ex. 36+	Totals
Fettlers and Dressers	37	44	41	24	24	24	26	220
Moulders	2	1	6	3	7	4	13	36
Crane Drivers	1	—	—	—	1	3	2	7
Welders and Acetylene Burners	5	1	1	3	1	—	—	11
Sand and Shot Blasters	2	5	1	1	—	—	—	9
Furnacemen	3	1	1	1	—	1	1	8
Others	5	6	10	5	6	3	10	45
Totals	55	58	60	37	39	35	52	336

The periods of exposure range from under 10 to over 40 years. The average periods are:

	Years
Fettlers and Dressers	19·4+
Moulders	29·9+
Welders	15·0+
Sand and Shot Blasters	15·3+
Crane Drivers	29·1
Furnacemen	23·0
Others	23·8+

The "scatter" of the recorded period of exposure shows a heavy preponderance of cases (223 out of the 336) in the 16 *plus* range; and 163, or practically half, in the 21+ range.

These figures are in line with what is already known with regard to this aspect of the problem.

(*f*) *New Cases* (*Silicosis*)

Seventeen "new" cases of silicosis have been identified as having developed during the period the scheme has been in operation.

This is less than 3 per thousand of total *employment* spread over 5 years, an average of less than five per ten thousand employees per year.

Sixteen of these cases are amongst fettlers and dressers, the other one is a welder. The average periods in those cases of exposure to the hazard, prior to the observation of lung change have been:

	Years
Fettlers and Dressers	19·2
Welder	7·0

The last figure is so small as to be regarded with some suspicion.

The degree of disability is known in only ten of these cases. In 9 of them there is none and in the other the disability is slight.

Only 12 firms have produced any new cases at all during the five years under review, and only five (with 2 each) more than one.

(g) *Coal Miners' Silicosis*

Thirty-one cases of coal miners' silicosis have been identified, in addition to the 336 "back-log" and the 17 new cases.

The "miners" cases have been kept quite separate, as they all involve disease contracted prior to entry into steel foundry employment. An important consideration may be whether all or only some of these men were known as silicotics at the time of entry into the industry. There is also the question of "aggravation". But these may be matters of legal, rather than medical significance.

The present foundry occupations of these 31 men are:

Fettlers and Dressers	8
Welder	1
Miscellaneous	22
	31

Their degrees of disability are as follows:

None	8
Slight	8
Severe	2
Not known	13
	31

(h) *Siderosis*

Cases of siderosis identified during the survey number 69:

(a) Back-log	54
(b) New cases	15
	69

They occur almost entirely amongst welders.

	Siderosis Back-log	*New Cases*
Welders	52	14
Fettlers and Dressers	2*	1*
	54	15

* These had all previously been mainly occupied as welders.

The average period of exposure is well over 20 years for the back-log, and over 14 years for new cases.

In only 12 of the siderosis cases is there any recorded disability, and only 2 of those are severe.

F. CONCLUSIONS

Approximately 15,000 foundry workers are employed by firms which are members of the B.S.F.A. Of these, 57% were examined and form the basis of this report. The following conclusions can be drawn from the survey:

(1) A tremendous preponderance of "back-log" cases arose in a period before the cause and means of prevention of silicosis were known.

(2) Silicosis, even after a long period, is not necessarily a disabling disease and the proportion of cases in which the degree of disability is severe is relatively small.

(3) A very small number of deaths has occurred amongst the cases identified, and where the reason for death is known, silicosis was not the cause.

(4) The number of new cases, i.e. cases which have developed during the course of the survey, is so small that it cannot be expressed as a percentage, being something less than three per thousand of total employment, spread over five years; an average rate of less than five per ten thousand employed per year.

(5) From the above findings it would appear that silicosis as an industrial risk in steel foundry workers is rapidly disappearing, but it is possible that, in dealing with a slowly progressive disease, five years is not long enough to be absolutely certain.

G. FURTHER WORK THAT COULD BE DONE

It should be appreciated that the present report is only a preliminary survey of the material we have obtained, relative to the incidence of pneumoconiosis in the Steel Founding Industry. It is not a complete and final analysis of all the information we have managed to collect. We think that careful consideration of this information, together with future information, which we think should be possible to obtain, might well enable us to form other worthwhile conclusions.

(1) It seems desirable that the annual X-raying of the workers' chests should continue for the time being. It is possible, though on the whole unlikely, that the blackout conditions during the war resulted in a higher percentage of men contracting pneumoconiosis. If this were so, they should be manifesting radiological evidence of the disease within the next few years. It would be valuable to prove whether this was so or not.

(2) It would he of extreme value to determine the radiological changes in all cases of pneumoconiosis, both hack ones and new cases, to assess the rate of progress, if any, over a period of seven years. This might necessitate reviewing the X-ray pictures, but this could easily be done. As far as we are aware no comparahle work has ever been done.

(3) As mentioned in the introduction to the report, it had heen hoped to he able to compare the rate of progress of the disease, in men who had changed their occupation when the abnormality was detected, with those who had remained at the same occupation. At present we have not got sufficient information to make this comparison, hut it should he possihle to ohtain it, and it should prove of considerahle value.

(4) No attempt has been made in the report to determine the incidence of active pulmonary tuberculosis iu cases of pneumoconiosis. It is widely believed that persons suffering from pneumoconiosis are much more liahle to contract tuherculosis than those not so affected. We have often heard this stated in law courts. Our impression is that our present study does not suhstantiate this theory. If this is so, it would he valuable to put it on a factual basis.

(5) As already mentioned, since starting on the report we have had replies from 4 foundries. These include some 80 cases of pneumoconiosis. These we think should he analysed in the same way as the others.

(6) A more careful investigation into the occupational history of those cases of silicosis classified under the heading of "others" might well provide useful information.

(7) A further scrutiny of the mass of material at our disposal would, we feel sure, reveal many other lines of useful research.

We should like to thank most sincerely the B.S.F.A. Statistical Staff for the ungrudging help they have given us.

(Signed) A. LISLE PUNCH
L. G. BLAIR

APPENDIX II

Steel Founding Safety Campaign

British Steel Founders' Association

In November 1955, the British Steel Founders' Association set up a special Safety Committee with the two-fold function of preparing a programme of activity for the purpose of reducing the incidence of accidents in the industry; and of devising means of assessing the present accident rate in the industry and measuring the effectiveness of the Association's campaign.

It was early found that the second function must be given precedence in time. The Committee decided that it should attack the problem item by item. This necessitated an attempt to identify culprit processes, and other factors, which would enable concentration of effort and the determination of priorities.

The most interesting fact to emerge is that steel foundry accidents are not primarily attributable to specific processes in the foundries. The great majority of accidents is due to general factors, not peculiar to steel foundries, but falling broadly under the heading "bad housekeeping". This heading seemed to the Committee to present too broad a front for its initial attack. It therefore decided to concentrate, at the outset, on the first two factors to which the Chief Inspector of Factories had already drawn attention, viz., eye injuries and foot injuries.

The attack on eye injuries was launched by the issue of a pamphlet addressed to operatives in all B.S.F.A. foundries and a striking poster was designed for display in conjunction with the issue of the pamphlet.

The pamphlet addressed to operatives had an original print of 20,000 copies which was rapidly exhausted, and a further reprint of 10,000 copies has been made. Much interest has been shown in this publication in Great Britain, and abroad, particularly in the United States of America, where the Steel Founders' Society of America have asked for, and have been sent, a bulk supply for special distribution among their own Membership.

In regard to foot protection, the Committee made a special enquiry and was surprised to find how few operatives who suffer damage to their feet are, in fact, wearing safety footwear.

It would not be true, of course, to say that all injuries to feet could be prevented by the wearing of safety footwear, but, quite obviously, not only could a great deal of this damage be prevented altogether, but the severity of such damage as cannot be avoided could be enormously reduced.

The campaign against foot injuries followed the same general lines as that against eye injuries in that pamphlets dealing with foot protection were issued to foundry operatives employed by all B.S.F.A. Member firms who were supplied with specially designed posters for display in this connection.

The British Steel Founders' Association proposes to continue this campaign, keeping its feet firmly on the ground, and dealing with the problem item by item—either by protection of particular parts of the body specially liable to injury, by identification and correction of culprit processes, or by direct encouragement of safe methods of working in defined circumstances.

APPENDIX III

Observation and Photography of Dust Clouds

1. Dust particles less than five microns in diameter are generally considered the most dangerous and these particles are invisible in ordinary lighting conditions. Prior to 1950 dust clouds consisting of particles within the respirable size range were investigated by means of instruments which sampled them, when the dust particles in the samples could be examined under a microscope, by chemical analysis, by X-ray diffraction methods and so on. These methods, however, gave no indication of the locus of moving dust clouds in foundry conditions and, in fact, a statistical analysis of the samples taken before the publication of the earlier report[2] gave certain anomalous results[10]. This led the Committee to the view that some attempt should be made to discover new methods by which dust clouds within the respirable size range could be observed as they moved through space[2]. A member of our Committee, Mr. W. B. Lawrie, investigated this problem and devised a technique by means of which the dust clouds could be both seen and photographed on cinematograph film[12].

2. When a beam of light is passed through a suspension of particles in a gas or a liquid, the resultant scattered light makes the path of the beam easily visible, particularly if the experiment is done in darkness with a beam providing the only light source. The phenomenon is sensitive to relatively low concentrations of small particles and many of the optical effects have been the subject of fairly full theoretical investigations. Tyndall had shown that when the particles were less than the wave length of the incident light, the scattered light would be blue in colour and transmitted light would be red. Rayleigh evolved a general expression and showed that with very small particles this scattering was symmetrical and that at 90° to the incident beam the scattered light was completely polarised. Mie extended the work to larger particles and showed that more light was scattered in a forward direction as the particle size increased. In these conditions the plane of maximum polarisation also moves forward towards the exit direction of the beam. Particles 0·1 micron in diameter scatter slightly more light forward than they scatter backward. One micron particles scatter most of the light forward within 15° of the beam, while five micron particles also scatter chiefly in a forward direction and within 5° of the beam.

3. The theoretical work was only valid for clouds in which the particle sizes fell within a narrow range and this condition would not be met in foundries. It was appreciated, therefore, that the method could not easily be used quantitatively and it has, in fact, only been used qualitatively. Dust concentrations and size ranges, however, can be determined by normal methods and it was thought that there would be sufficient light in the area of forward scatter to make the commonly existing dust clouds visible. Experimental work[12] showed that this was the case and the technique showed the presence of airborne dust clouds, their point of origin, the paths along which they move and gave clear indication of the differences in dust concentration which commonly occurs in different parts of a dust cloud. The original work[12] also showed that it was possible to photograph the moving dust clouds by means of a 35 millimetre

cinematograph camera and Figures 1, 2 and 3 are reproduced from the first film that was taken. Later work indicated that similar photographs could be obtained on the 16 millimetre cinematograph camera, although this camera bears all the disadvantages normally associated with the smaller negative. The mere observation of dust has been of great assistance in engineering development and the photography has provided still further information because the path of a rapidly moving dust cloud can be examined in detail frame by frame, if necessary, on the cinematograph film. High-speed cinematography has also been used in certain cases to give slow-motion pictures, but for most of the work normal camera speeds have proved sufficient.

Fig. 1. Fine dust cloud rising from pneumatic chisel. No exhaust ventilation in use.

Fig. 2. Dust stream flowing from hood of stand grinder. Conventional local exhaust ventilation fitted and operating.

Fig. 3. Dust cloud generated by portable abrasive wheel. No local exhaust ventilation in use.

APPENDIX IV

Dust Assessments in Steel Foundries

A Communication from the British Steel Castings Research Association

The British Steel Castings Research Association has devoted a considerable amount of effort over a period of several years to the development of sampling techniques for airborne dust in foundries. The best known dust sampling instruments are the Konimeter, the Owens Jet and the Thermal Precipitator. All of these, however, have their particular disadvantages for use in foundries for the routine assessment of dust concentration. Instruments for this purpose should be robust and easily handled and the evaluation of the dust samples should, preferably, be easily conducted by personnel relatively unskilled in laboratory techniques.

The Konimeter and the Owens Jet are both impingement collectors. In both a small sample of air is drawn by a hand pump through the instrument and impinges on a glass plate where the dust in the air is deposited. Although both instruments are light and easy to use they both suffer from the disadvantage that the assessment of the sample is tedious, since it must be examined microscopically and the size distribution of the dust determined either by particle counts or by comparison with reference slides or photographs of standard dust concentrations. There is also the further disadvantage that in both instruments it is believed that the impingement on the collector plate shatters large particles of dust leading to exaggerated values for the concentration of particles less than 2 μ in size.

These instruments are "snap" sampling instruments, i.e. they sample only a small volume of dust-laden air over a period of a few seconds. Such measurements are useful to study the variation of dust concentration in space or in time, but in order to obtain information on average conditions of dust concentration it is necessary to take large numbers of samples and to treat the results on a statistical basis. This procedure has been used to make surveys of airborne dust concentrations in steel foundries[2, 11], but it is tedious and time consuming.

The Thermal Precipitator collects dust by thermal deposition on a glass plate located close to a hot filament. It is a very efficient sampling instrument and has come to be regarded as a standard instrument with which other dust collecting instruments are compared. Unfortunately it is a delicate instrument and in its usual form is not sufficiently robust for routine use in foundries. Normally the sampling period for the thermal precipitator is of the order of 20 minutes. Attempts have been made witb some success to make the instrument take continuous dust samples over a long period of time, but the instrument still suffers from the considerable disadvantage that the samples must be assessed by tedious microscopical examination.

In order to obviate tbe time-consuming process of visual examination of dust samples collected with these instruments, attempts have been made to develop automatic dust counting equipment for this purpose. The Association has contributed financially to one of these developments, viz., the work at

University College, London, on the development of the "flying spot" microscope. Recent accounts of the development of this instrument[18] have shown that automatic counting by this means gives results in good agreement with visual counting. The equipment involved is, however, complicated and costly and for this reason it is likely to remain a specialised laboratory apparatus and is not likely to be installed in foundries for routine dust assessments.

Although for many purposes, for example the study of the efficiency of local exhaust ventilation, short term sampling of foundry atmospheres is required, such measurements, except when taken in large numbers and treated statistically, do not directly assess average conditions of dustiness. It may be argued that, since silicosis is a disease which only develops after a long period of exposure, measurements of long term average dust concentrations are more relevant to the assessment of this health hazard and, consequently, the Association and similar organisations have been concerned with the development of long range sampling instruments. Apart from the requirement that the instrument should sample the atmosphere continuously over a shift period, there are two other requirements which it is desirable that such an instrument should meet in order to give a direct assessment of the silicosis hazard. These are, first that the dust collected should be reasonably representative of the inhalable fraction of the dust. This implies that the instrument should collect only particles less than about 5μ in size. The second requirement is that the sample collected should be sufficient in amount to permit an analysis to be made of the constituents present in the dust, in particular the proportion of free silica which is present in it.

THE "HEXHLET" SAMPLER

An instrument which fulfils these requirements is the Hexhlet sampler, which was developed by the Pneumoconiosis Research Unit[15]. With this instrument, the dust concentration is assessed gravimetrically and not in terms of particle counts. Before describing the instrument it is as well to devote some attention to the question of the validity of mass concentration as a means of assessing dust hazards on a comparative basis.

Medical opinion has for some time favoured the use of particle count figures for the measurement of health hazards[73]. This method has been favoured in preference to measurement of mass concentration because the latter method may give misleading results if the size distribution of the dust particles varies substantially over the environments which are to be sampled. The mass of a particle, assumed to be spherical of radius r, is given by

$$m = \frac{4}{3}\pi r^3 d$$

where d is the density of the material constituting the dust. Thus for dust of a particular substance (i.e. constant d) the mass concentration is proportional to the cube of the particle size. A variation of particle size distribution can therefore render the comparison of dust concentration on a mass concentration basis invalid and, before a dust assessment depending on mass concentration can be recommended, it is necessary to ensure that the size distribution of the dust does not vary substantially between the atmospheres which are to be compared.

Prior to the adoption of the Hexhlet instrument for the routine measurement

of atmospheric dust concentrations in foundries, therefore, the British Steel Castings Research Association made an assessment by means of Owens Jet samples of the particle size distribution in the atmospheric dust from a number of foundries, to discover whether the assumption of a fairly constant size distribution could be justified by actual observation. Fig. 4 shows the results

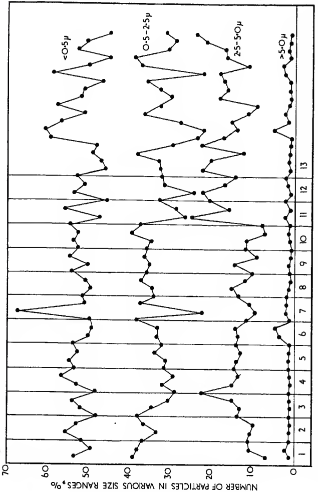

Fig. 4. Size distribution of dust in the general atmosphere of fettling shops in thirteen foundries as sampled by the Owens Jet Dust Counter.

obtained in 55 samples taken in 13 different foundries. From these results it will be seen that the particle size distribution of the airborne dust remains sufficiently constant between different foundries to justify the acceptance of a mass concentration criterion for an assessment of the health hazard in foundry atmospheres.

The Hexhlet instrument which samples in terms of mass concentration is also size selective. It incorporates an elutriator which is designed to simulate the function of the human respiratory tract[74] and rejects particles which would not reach the lung during normal respiration.

A diagrammatic sketch illustrating the working of the Hexhlet sampler is shown in Fig. 5. There are five main parts to the sampler:—the elutriator, the orifice and gauge, the paper Soxhlet thimble, the evacuation chamber and the air ejector.

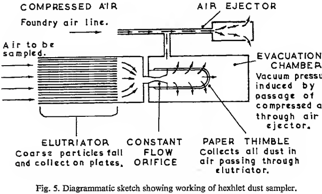

Fig. 5. Diagrammatic sketch showing working of hexhlet dust sampler.

The Elutriator

The elutriator consists of 2 banks of 58 aluminium plates having an upper surface area of 1,690 sq. in. upon which 50% of the dust particles having the free falling speed equal to that of a 5 μ sphere of unit density and all the particles having the free falling speed of a 7 μ sphere of unit density deposit by gravitational settlement and do not, therefore, pass into the collecting stage of the instrument. This portion of the instrument thus reproduces the function of the upper part of the human respiratory tract and removes, from the dust which is collected, those coarse particles which, in normal respiration, would not reach the interior surface of the lung.

The Air Ejector and Evacuation Chamber

The air ejector is connected to a compressed air line and induces a partial vacuum in the evacuation chamber, which draws the air to be sampled from the shop atmosphere through the constant flow orifice and collecting thimble. A sound damping chamber to minimise noise is an essential part of this ejector.

The Constant Flow Orifice

Having passed through the elutriator, the dust laden air passes through a constant flow orifice, which is calibrated to give a constant flow of 100 ± 1 litres per minute. The instrument is designed to operate from normal compressed air lines and any line with a pressure greater than 30 lb. per sq. in. applied to the air ejector will suck the dust-laden air, which is to be sampled, through the constant flow orifice at this rate. A pressure gauge, which measures the vacuum pressure induced by the air ejector, is directly behind the orifice, and is calibrated in millimetres of mercury. As long as the gauge needle remains above the red line at the 100 mm. mark a constant sampling rate of the contaminated air at 100 litres per minute will be maintained through the instrument.

The Soxhlet Thimble

The paper thimble is situated directly behind the critical flow orifice in the evacuation chamber and collects all the dust suspended in the entrained air from which the coarse particles have already settled out in passing through the elutriator.

Assessment of Samples

A crude assessment of the dust is obtained by weighing the paper thimble before and after collection of the dust. In general, however, this metbod is not to be recommended, since the variation of weight of the paper thimble with atmospheric humidity is not inconsiderable and this introduces an error into tbe determination of the dust, which is by no means negligible. One of two alternative methods must, therefore, be used.

(i) If it is desired to estimate the carbonaceous as well as the mineral constituents of the dust, the dust sample may be washed out of the thimble by dripping onto it continuously a suitable liquid, e.g. acetone. By continuing this process for a sufficient length of time as much as 95% of the dust is washed out, and is then removed from the liquid by centrifuging and drying and assessed by weighing.

(ii) If the carbonaceous portion of the dust is insignificant in amount, and this is normally the case for foundry dust samples, the sample is assessed by incinerating the paper thimble and assessing the dust by weighing, with an appropriate correction for the weight of the thimble ash. Acid hardened thimbles are available for this purpose, which have an ash content of 4 mg. constant to ± 1 mg. This method is normally used for foundry dust samples and it has been shown that incineration at 700°C in air does not alter the constitution of the dust in a manner substantially affecting the accuracy of the measurement. Some of the Fe_3O_4 present in the dust is converted to Fe_2O_3, but this does not introduce any significant error into the measurement. The dust concentration is normally expressed as milligrams per 100 cu. ft. of air drawn through the sampling instrument.

The gravimetric assessment made as described above, gives a measure of the total dust concentration in the atmosphere, which is to be sampled. To obtain more precise information on the constituents present in the dust, an analysis can be carried out on the dust sample after extraction from the thimble. The amount of dust collected under average foundry conditions during a shift is on an average of the order of 50 mg. in weight and this is adequately large

for detailed chemical analysis by semi-micro chemical methods. A valuable supplementary method of analysis is examination of the dust sample by X-ray diffraction. This not only enables all the crystalline constituents of the dust to be identified, but is the most reliable method for the determination of the quartz fraction of the dust. X-ray diffraction patterns of dust samples photographed under standard conditions are compared photometrically with photographs of standard synthetic samples with known quartz contents and the quartz present in the industrial dust may by this means be estimated reliably with an accuracy at least as high as $\pm$ 1%.

Some reference should also be made to an alternative method of dust assessment which has been the subject of investigation by the British Steel Castings Research Association[13]. This is the nephelometric method, in which a quantitative measurement of the dust is obtained by dispersing the dust as a suspension in a suitable liquid medium and measuring the amount of light scattered when a beam of light traverses the suspension. The amount of light scattered is directly proportional to the total surface area of the particles in suspension. It was hoped to use this method to make a direct assessment of the quartz fraction of the dust by using two suspension media of different refractive index, one (benzaldehyde) having a refractive index similar to that of quartz. This method did not, however, prove to be of the required order of accuracy, possibly because the surface of the quartz particles had a contaminated surface, e.g. dead clay films, and, because of this complication and the generally greater convenience of the gravimetric method, this method of assessment has now been abandoned for routine dust assessment.

Summary

For the routine evaluation of average dust concentrations in foundries, the Hexhlet sampling instrument is to be recommended, since it enables long-term samples to be taken and collects a sample sufficiently large for detailed analysis of the constituents present in the dust to be readily performed. The use of a mass sampling instrument of this type is justified by the relative constancy of the size distribution of airborne dust in steel foundries. Long-term sampling by this method may be supplemented by short-term sampling using snap samplers, such as the Owens Jet, when information is required on variations of dust concentrations with space and time.

Acknowledgement

The Association acknowledges the financial assistance which it has received over a period of years from the British Steel Founders' Association to support its work on this and associated problems relating to health problems in steel foundries.

APPENDIX V

The Wet De-coring Bar

1. A member of the staff of the British Cast Iron Research Association, Mr. W. H. White, has designed a bar for wet de-coring[20]. An ordinary bar has been fitted with a ring which carries four jets from which a fine spray of water can be projected round the point of the bar. When the bar is in use for hand de-coring, the water spray reaches the core before the point of the bar strikes it, so that the core sand is wetted before being dislodged. This is, therefore, an attempt to eliminate dust at source and not a dust control method, because the moistened sand will be dust free even when it is knocked out of the casting by the bar.

2. The device was examined by means of the illumination technique and proved eminently successful on the cores on which it was used[20]. Figure 6 shows the conditions immediately after de-coring with the ordinary hand bar, and Figure 7 shows conditions after de-coring by means of the new wet bar.

Fig. 6. Conditions after finishing dry de-coring. Note atmospheric dust cloud.

3. A short series of dust counts was also taken during the experimental work on the process[20]. The Owens Jet Counter and the Thermal Precipitator were used and the samples, which were taken at the breathing level of the operator, were not incinerated. The results confirmed the observations made by the illumination technique.

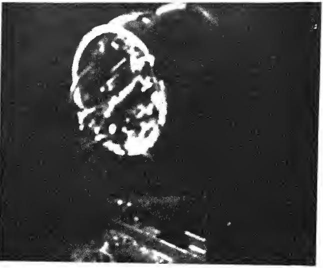

Fig. 7. Conditions after finishing wet de-coring.

The Owens Jet samples[20] were estimated[6, 7] and gave a general atmosphere dust concentration of about 1,000 particles per cubic centimetre before starting work. This remained constant during the wet de-coring, but rose to 3,600 particles per cubic centimetre after dry de-coring. This latter sample was taken at the same time as the photograph which forms Figure 6, which was about two minutes after the dry de-coring process had ceased so that the heavy dust would have had time to fall out of the atmosphere.

The Thermal Precipitator samples were counted under light field illumination to the limit of visibility. This instrument showed a dust concentration of 869 particles per cubic centimetre before starting work with a concentration of 924 particles per cubic centimetre after wet de-coring. Dry de-coring by the old method gave a corresponding dust concentration of 6,980 particles per cubic centimetre at the end of the process.

The bar is now in day-to-day use in iron foundry dressing shops, and months of practical experience have shown it to be satisfactory in normal working conditions.

APPENDIX VI

Use of Silica Flour in Steel Foundries

A Communication from the British Steel Castings Research Association

Although its use as a parting powder is forhidden, silica flour is still used for two purposes in steel foundries, firstly as a refractory base for mould paints or washes and secondly as a filler in moulding sands. In hoth applications the fine silica flour fills the voids between the sand grains, the paint at the face and the filler in the depth of the mould, and so prevents penetration of metal into the sand causing adherence of sand to the casting. An addition of silica flour also increases the dry and hot strengths of sand and therehy improves its resistance to erosion by molten metal. By promoting a good casting strip and an easy sand peel, the use of silica flour lessens the amount of cleaning and fettling that would he required and so improves the atmospheric conditions and danger to health in the fettling shop. Whilst alternatives to silica flour, notahly zircon, hall clays and siliceous fire clays are being used quite successfully in a large numher of steel foundries, there are, however, certain castings, e.g. large or of complicated design, where these suhstitutes are not applicahle, and silica flour has to he used either as a paint or filler in order to get a satisfactory strip. Any health hazard that might arise from mixing or milling operations when using silica flour has, however, heen overcome hy using silica flour in the dampened form. Silica flour containing 6–12% added water, from which airhorne dust cannot be generated, can now he readily ohtained from suppliers.

The possihle use of a fine silica sand (150–300 mesh) as a mould paint and filler in place of silica flour was examined hy the Association, hut was found to give much inferior results hoth with respect to moulding quality and to casting surface finish. Sponsored work hy the Association at Camhridge University on the use of basic refractory materials as mould washes, showed these to he much less satisfactory than the siliceous and silica flour based washes. Similar work, however, is to continue with the aim of improving present paint compositions and developing new compositions that may lead to hetter and easier casting strip. This work is included in a priority research project of the Association, in which the various factors affecting the surface quality of castings are studied.

APPENDIX VII

The Powder Washing Process for the Cleaning of Steel Castings

A Communication from the British Steel Castings Research Association

The development in the U.S.A. of the powder washing process for the cleaning of steel castings first became generally known to British steel founders in the latter part of 1951. The first British-made prototype torch was tried under production conditions early in 1952. This process should not be confused with that in which the powder burning torch is used for metal cutting[21]; it is in fact the commercial development of the conception of a "flame chisel" referred to in an earlier Report[75].

Design and Construction

In this method use is made of the exothermic oxidation of iron powder injected into an oxy-acetylene flame to assist in the melting and removal of excess metal from steel castings in the "as cast" condition, and of the slagging reaction between iron oxide and silica for the removal of adhering sand. Thus the process can be said to be an alternative to pneumatic chiselling and grinding for this purpose.

The torch used is similar to a normal oxy-acetylene burner with the addition of a third feed pipe, running parallel to the oxygen and acetylene feed pipes, through which the iron powder is supplied from a dispenser unit, and injected by compressed air at about 6 lb./sq. in. pressure into the oxy-acetylene flame through a fish-tail nozzle. Cutting nozzles are available in a range of sizes to suit different applications of the torch. Photographs of the torch and the wheel-mounted powder dispenser are reproduced in Figs. 8 and 9.

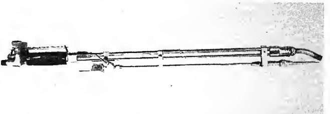

Fig. 8. The Powder Washing Torch.

In the early years of the introduction of this technique into the British steel foundry industry, the British Steel Castings Research Association, in collaboration with a number of its Members, conducted a series of trials, the results of which assisted in establishing features of the design and construction of the torch and the powder dispenser advantageous to the efficiency of operation and to

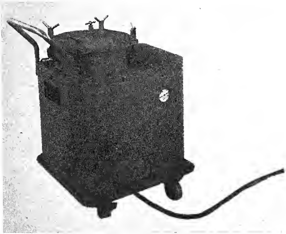

Fig. 9. The Powder Dispenser for the Powder Washing Process.

the comfort and convenience of the operative. A comparatively wide range of iron powders of different chemical and physical properties was also examined with a view to finding an alternative to the then relatively high-priced electrolytic iron powder recommended by the manufacturers. These latter tests showed that powder of low carbon content is essential for satisfactory operation of the process and for the avoidance of excessive fume. Since the price of this powder has been more than halved since 1951, the process has become an economic one in many applications for the cleaning of steel castings.

Application

The powder washing torch has been found particularly advantageous for the removal of areas of the surface of the casting where the metal has penetrated the moulding sand or where sand adheres firmly to the surface of the casting. Hitherto the commonest method for cleaning such surfaces has been the pneumatic chisel and in such applications siliceous dust is unavoidably created. Powder washing has been shown to remove such adhering sand equally as fast, or faster, than the pneumatic chisel without generating siliceous dust, and its use is particularly effective in removing adhering sand from regions of castings which cannot readily be reached with chisels, e.g. cored out cavities. Similarly, the process has found application for the removal of scabs and other surface defects caused by the inclusion of sand within the surface of the casting.

The other fields of application for the torch are in the removal of excess metal, such as the stubs of risers and runners, sprigs, flash and excess weld metal. It may also be applied to the cutting out of cracks preparatory to welding. In most of these applications it may be said to take the place of grinding rather than the pneumatic chisel.

The extent to which the powder washing torch may be applied in any particular foundry depends partly upon the quality of casting surface finish required by the foundry's customers. It is clearly uneconomic to utilize the process if subsequently further cleaning by chiselling or grinding is required to obtain an acceptable standard of finish.

Operating Conditions

While the use of the powder washing torch undoubtedly reduces the volume of dust generated in the cleaning of steel castings, it does cause some discomfort to the operator through the amount of heat generated, and is also responsible for the emission of iron oxide fume from the burning of the iron powder in the oxy-acetylene flame. The degree of discomfort and the extent of the possible hazard to health presented by these two factors are not known, but in general their effect is thought to be less deleterious than the dust which would be created by alternative means of carrying out the operations to which the powder washing torch is applicable. It is of interest to note that air-fed respirators have been found particularly useful in improving the comfort of operators engaged in this process.

APPENDIX VIII

The Air-Carbon Arc Torch

A Communication from the British Steel Castings Research Association

The Air-carbon Arc Torch, which was developed in the U.S.A., was first introduced to this country by the B.S.C.R.A., who regard it as an important development in fettling techniques for steel castings, since it provides a partial replacement for the pneumatic chisel primarily for the removal of defective areas of castings prior to welding and for the removal of excess metal. Not only is it speedier in operation than the chisel and in many cases more economic, but its use is also associated with less risk of generating dust containing free silica and it is markedly less noisy than the pneumatic chisel.

The principle of operation of the torch is the striking of an arc between the carbon electrode and the casting, which melts the metal, which is then blown away by a jet of compressed air blowing along the electrode. By this means a clean slag-free cavity is produced ready for welding without any further preparation.

Design and Operating Procedure

The torch is shown in Fig. 10. It comprises a hollow insulated handle through which compressed air and electric current from a D.C. welding generator are supplied to the electrode clamp. The compressed air emerges from the clamp through two accurately aligned ports so located to cause both jets of air to travel parallel to and on the same side of the electrode. In operating the torch, it must be so held that these air jets are behind the electrode in relation to the direction of the gouging.

Fig. 10. The Arcair Torch.

Copper-coated graphite electrodes are normally used because of their lower rate of consumption and improved resistance to breakage compared with uncoated electrodes, which become tapered to a sharp point due to the action of the air stream. The electrode diameter is chosen to give the required rate of metal removal, and electrodes up to $\frac{3}{4}$ in. dia. are used in steel foundry dressing shops.

It is generally agreed that a high current is required for the efficient use of the torch, the rate of metal removal increasing rapidly with operating current, as shown in Fig. 11. For this reason the D.C. generator used in conjunction with the torch should be capable of delivering 1200 amps and the torch is normally operated at a current of at least 600 amps. A stable and continuous arc can only be achieved by connection of the electrode to the positive pole of the generator. This reversal of normal polarity makes essential the provision of a good earth connection.

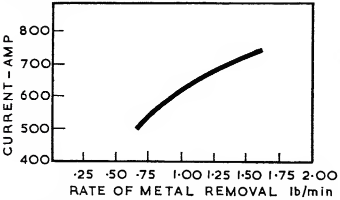

Fig. 11. Relation between the current and the rate of metal removal by an Arcair Torch.

The maintenance of an adequate air pressure at the torch is of extreme importance and a minimum pressure of 80 lb./sq. in. *at the torch* is recommended. At lower pressures the molten steel is not adequately removed from the point of gouging.

Examples of the Use of the Torch

Table I illustrates the economic advantages in a steel foundry, which have been attained by the use of the air-carbon arc torch as compared with normal fettling procedures. This Table gives details of the times required to fettle the same type of casting with and without the aid of the torch. On average the time of fettling was reduced by nearly 50%.

Fig. 12 shows a typical example of the quality of surface finish attained after the removal of excess metal by the torch. It can be observed that the contour of the curved faces was well formed and no subsequent grinding was required, as is indicated by Table I. The casting, after gouging, was photographed before it was heat treated and shot blasted, which would further improve its appearance.

TABLE I

Comparative Data on Dressing Castings by Pneumatic Chisel and Grinding and by Arcair Torch (Courtesy of Bonnington Castings Ltd.)

Casting		No Arcair Torch Used Time Taken			Arcair Torch Used Time Taken				Saving	
Description	Weight lb.	Dressing	Grinding	Total	Dressing	Grinding	Torch	Total	Min.	%
Rope Drum	146	100 min.	16 min.	116 min.	25 min.	Nil	30 min.	55 min.	61	53
Rope Drum	357	100 min.	36 min.	136 min.	25 min.	Nil	25 min.	50 min.	86	63
2 in. Valve Body	65	35 min.	8 min.	43 min.	15 min.	Nil	7 min.	22 min.	21	48
3 in. Valve Body	68	23 min.	9 min.	32 min.	12 min.	Nil	10 min.	22 min.	10	31
6 in. Valve Bonnet	56	25 min.	6 min.	31 min.	12 min.	Nil	4 min.	16 min.	15	48
Spring Saddle	57	35 min.	3½ min.	38½ min.	12 min.	Nil	8 min.	20 min.	18½	48

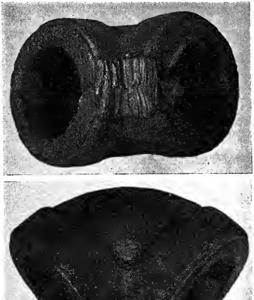

Fig. 12. Showing castings before and after the removal of excess metal by the Arcair Torch.

The relative speed of gouging by a chipping hammer and by the air-carbon arc torch may further be judged by Fig. 13, and the data provided in Table II. The cavities shown in Fig. 13 were prepared in a scrap casting solely for the purpose of this investigation and not to remove defects. Had defects been present, the method would have been the same and repair by welding without further dressing would have been possible. The data given in Table II shows that the time taken to excavate this cavity with the air-carbon arc torch was 72% less than the time required when using a chipping hammer.

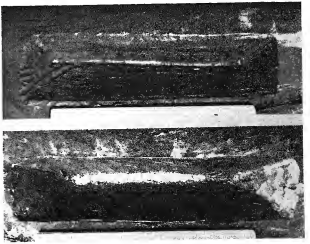

Fig. 13. Showing the cavities cut by chipping (top) and by an Arcair Torch (bottom).

TABLE II

Results of Cutting a Cavity by a Chipping Hammer and by an Arcair Torch (See Fig. 13) *(Courtesy of The English Steel Castings Corporation Ltd.)*

	Size of Cavity	Volume of Cavity	Time of Gouging	Time of Gouging per cu. in. of Cavity	Saving of Time %
Chipping Hammer	15 in. × 4 in. 3 in. deep	81 cu. in.	11 hr. 37 min.	8 min. 36 sec.	—
Arcair Torch	15 in. × 4 in. 3 in. deep	87 cu. in.	4 hr. 47 min.	3 min. 18 sec.	72

Metallurgical Considerations

It has been suggested that the use of the air-carbon arc torch is attended by dangers of carbon pick-up from the electrode and the initiation of cracks in the casting or the propagation of cracks already present. Extensive experience

in American and a few British foundries has not, however, confirmed that any serious risks are involved in using the torch on low carbon steel castings. Provided that an adequate air pressure is maintained to blow away the molten steel, the risk of carbon pick-up is negligible and cracking tendencies in this type of steel are non-existent. It is usually considered, however, that some risk of cracking adjacent to the gouge exists if the torch is used on air-hardening steels and it is considered that, if a steel is of a composition which should be preheated for welding, it should also be preheated before it is exposed to the air-carbon arc torch.

Application of the Torch

The normal application of the torch is for the gouging out of defects, e.g. shrinkage tears, or for the removal of excess metal, e.g. riser stubs and pads. In the former context, it performs a function usually performed by the pneumatic chisel, and in the latter it may be used as an alternative to pedestal or swing frame grinders. It cannot, however, be used with complete success to replace the pneumatic chisel for the removal of burnt-on sand on steel castings. A sand layer on the surface of a casting effectively insulates the casting from the electrode and sand can only be removed by undercutting, which makes a cavity undesirably larger than when using a pneumatic chisel. For the removal of burnt-on sand, powder washing is a more effective expedient than the air-carbon arc torch.

Health Hazards

A word of caution is necessary in relation to the use of the torch as a substitute for the chisel. Its use involves the generation of a certain amount of fume and, while this fume is essentially finely divided iron oxide, containing only a very small and probably negligible quantity of free silica, it is nevertheless important that operators using the torch should wear face masks to protect themselves adequately against this fume.

Conclusion

For certain fettling operations the air-carbon arc torch constitutes a valuable tool for use in steel foundries in the fettling of low carbon steel castings.

It is manufactured in this country by The Lincoln Electric Company Ltd. by a licensing arrangement with the Arcair Corporation of America and is known as the Arcair Torch.

Acknowledgement

The Association acknowledges the assistance which it has received from Bonnington Castings Ltd. for the data incorporated in Table I, and The English Steel Castings Corporation Ltd. for the data in Table II and the photograph, Fig. 13.

APPENDIX IX

Requirements for Efficient Dust Suppression at Foundry Knock-Outs
The British Cast Iron Research Association
Foundry Ventilation and Dust Control
B.C.I.R.A. Conference, Harrogate, 27th–29th April, 1955

Presented on behalf of the B.C.I.R.A. Foundry Atmospheres Committee by A. W. Evans* and O. H. Jacobson†

"This survey of methods of exhausting dust during knock-out operations was originally presented on behalf of the B.C.I.R.A. Foundry Atmospheres Committee by two of its members at a B.C.I.R.A. Conference[25] on Foundry Ventilation and Dust Control at Harrogate in April, 1955. It is reprinted from the Proceedings of this Conference."

Introduction

The design of satisfactory exhaust at knock-outs depends on a variety of factors, mainly comprising:—

(1) the size and type of casting and mould box;

(2) the nature of the moulding sand and its moisture content;

(3) the method of handling both the boxes and the castings;

(4) the location of the knock-out in relation to the foundry building with its access doorways, windows, etc. and prevailing cross-draughts.

In view of the variety of factors governing the exhaust hood form, it is impossible to lay down a basis of standard design. Each installation must be considered on its merits and should be the responsibility of engineers with special experience in this class of work.

With mechanisation it is necessary in most cases for air exhaust to be applied not only to the knock-out but also to the remainder of the sand handling system as required to prevent contamination of the general atmosphere of the foundry from these other sources.

The importance of keeping up the moisture level of all sand on floors, in transit, or subject to vibration cannot be over-emphasised. If the moisture content of the sand is not allowed to fall below about one-half of that normally required for moulding, no dust will be produced by any foundry operation.

Fundamentals of Hood Design

1. To prevent dust from entering the workers' breathing zone so that, although a dust cloud may exist, they will breathe wholesome air.
2. The point of exhaust to be as close as possible to the source of dust.
3. Enclosure round source to be as complete as possible.

In order to achieve the maximum efficiency at minimum cost the design of hood must take all the foregoing factors into account.

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* Air Control Installations Limited, Ruislip.
† Sturtevant Engineering Co. Ltd., London.

Air outlets can be controlled by mechanical means, such as a baffle-plate, louvres, etc., but an intake pipe cannot be so controlled. The crudest form of intake, an open-ended pipe, will draw air in from all round, even from behind, but by the addition of the back-plate, the inward flow of air is concentrated to the front (Figures 14(*a*) and 14(*b*)).

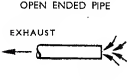


Fig. 14 (a). Open-ended pipe.

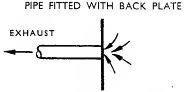


Fig. 14 (b). Pipe fitted with back plate.

In designing an efficient hood, the contour of the back-plate is of vital importance as a good design will achieve efficient results with a minimum rate of air extraction. With a bad profile an appreciable increase in the volume of air extracted will be necessary to achieve the same result. Most knock-outs deal with hot sand and cause the dust and fume laden air to rise above the knock-out with appreciable speed. The best extraction efficiency is obtained when this natural flow is used to assist the action of the hood (Figure 15).

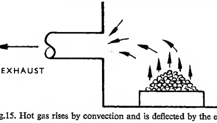


Fig.15. Hot gas rises by convection and is deflected by the exhaust.

The primary purpose of the hood is to prevent the fine dust and fume from reaching the breathing zone of the workers in the area, and to prevent it from spreading into the remainder of the foundry building. The layout of equipment in a foundry should therefore be planned so that adequate space is available for an efficient exhaust hood.

When planning new installations, consideration should always be given to locating the knock-out in a separate building or individual enclosure within the main building in order to simplify the design of the exhaust plant.

In the case of existing installations, the casting handling system adjacent to the knock-out may be such that an efficient hood is precluded. In such a case it may be necessary to alter the handling method so as to allow the accommodation of an efficient hood.

The proper location of the hood is of first importance and the method of handling mould boxes, returned empties and castings should therefore be planned initially in conjunction with the ventilating engineer.

Methods of Exhausting

(1) Fully enclosed knock-out
(2) Side Draught
(3) Down Draught
(4) Up Draught
(5) General Ventilation

1. *Fully enclosed knock-out*

The fully enclosed system is the ideal method of dust and fume control as the knock-out is provided with a complete enclosure with openings on the inlet side for the entry of the moulds and on the discharge side for the removal of castings and mould boxes. The relatively small area of the openings enables adequate exhaust to be provided with appreciably less air volume than for the other systems described, and is therefore considerably cheaper. As in the case of the side draught hood, there is no interference by the exhaust air with the constitution of the moulding sand and the system is largely protected from the harmful effects of cross-draughts in the building. It would appear that this system can be applied on fully mechanised plants employing standard mould boxes and on snap flask work. In the past, however, despite its substantial advantages, the system has only been adopted to a limited extent possibly because difficulties would be encountered in modifying existing plants. The system should be developed in future mechanised plants, but complete enclosure of the knock-out is both mechanically difficult and expensive compared with the other methods of dust and fume control.

2. *Side Draught*

Side draught is effected by means of a hood mounted above floor level and immediately alongside the knock-out point with a suction pipe connected to the hood.

The size and position of the suction opening must be governed by individual circumstances as explained earlier. The suction opening should be mounted in a screen above the level of the top of the mould box and on the side of the knock-out remote from the operator's working position. In this way the rising dust is drawn to one side of the grid and away from the operator. The top of the hood should be arranged to overhang the knock-out as far as is practicable. The hood should be located close to the edge of the long side of the knock-out and it is not sufficient for the vertical screen to terminate at a height of 2 feet or 3 feet above the box. If the knock-out is exposed to cross-draughts the area should be isolated by means of walls or side screens; failing this an exhaust of greater intensity will be necessary.

The side draught system maintains a constant rate of exhaust unaffected by the presence of large quantities of sand which frequently clog the knock-out grid and operates directly on the rising column of dust laden air so that this is drawn continuously away from the operators.

This type of exhaust deals only with the fine dust that is airborne above the moulds and does not influence the heavier dust and sand which normally falls into the hopper below the knock-out. In this way, the exhaust system is not subjected to heavy abrasive wear which occurs when excessive quantities of sand are extracted; maintenance is therefore reduced and the initial cost of the

installation is less, as it is not necessary to employ such heavy gauge ducting. The system does not extract so large a proportion of the smaller fractions of the sand as does a down-draught system.

A criticism often levelled at the side hood system is that it obstructs access to one side of the grid, but this limitation can frequently be overcome.

3. *Down Draught*

Down draught exhaust is effected by extracting air from the hopper or chute below the knock-out, either by nozzles extending along the length or width of the hopper or by shrouded suction openings made in the sides of the hopper. The effectiveness of the down draught system depends on its ability to achieve a complete reversal of the upward flow of the thermal currents generated by the hot sand moulds and castings before the dust and fume can reach the breathing zone of the workmen.

(*a*) Its effectiveness is limited to small castings that produce thermal currents of low velocity and volume contained in shallow boxes not exceeding 10 inches maximum height.

(*b*) The mould boxes must be standing on the knock-out grid and down draught alone will not be effective when boxes are knocked out when suspended above the grid.

(*c*) The precise relationship of box size to grid size that can be effectively dealt with will vary both with the shape of the grid and the box, the position of the box on the grid and the speed of the knock-out which controls the rate at which the sand falls through the grid.

(*d*) Moulding boxes should not exceed one-fifth of the total area of the grid on which they rest, and through which the down draught air is flowing, so that the falling sand cannot block the grid. This will ensure that the thermal currents rising above the centre of the box will be adequately influenced by the downward air movement.

The overall size of the knock-out grid used in a down draught system should not generally exceed 16 sq. ft. The box must, however, be placed centrally on the grid with ample space all round the box for the downward air flow.

This limitation on the size of the grid, together with a restricted proportion of grid to box area controls the maximum size of box which can be ventilated by a down draught system.

(*e*) The sand/metal ratio and the interval of time between pouring and knock-out should together ensure that only the sand adjacent to the casting is dry enough to release dust into the ventilating system.

A down draught ventilating system giving satisfactory control has the following advantages:—

(i) The dust and fumes do not rise more than a few inches above the box, and control is thus obtained close to the source.

(ii) There is no obstruction to access at floor level.

(iii) It is particularly suitable for highly-mechanised foundries producing large numbers of small but uniform light castings.

The principal disadvantages of the down draught system are:—

(i) It is restricted to small light castings in shallow boxes which must be knocked out on a relatively large-size grid.

(ii) The extraction of sand produces abrasion and the ventilating equipment requires more maintenance and cleaning than is usual with the side draught system.

(iii) The down draught system is not flexible and if the boxes or other factors exceed the upper limits of the design ratings, dust spillage will occur.

4. *Up Draught*

The up draught system with a canopy hood mounted directly above the knock-out prevents the escaping dust and fume from spreading into the general atmospere of the foundry and offers no obstruction to access around the knock-out. It does not, however, afford any protection to the knock-out operators, as invariably dust must travel through their breathing zone before reaching the hood. For this reason this type of hood does not fulfil the design requirements outlined earlier. The air volume and freedom from interference with the constituents of the sand are comparable with those of the side draught system.

5. *General Ventilation*

In the case of general ventilation, increases in the concentration of dust in the general atmosphere of the foundry building can be limited only by effecting a specified rate of air change, by introducing fresh air at low level and simultaneously extracting the fume laden air at high level and this affords no protection to the men working close to the source of dust. The general ventilation that is sometimes attempted by means of exhaust fans in the roof only, is often less effective than the combined system, as a system comprising exhaust only can draw dusty air from other parts of the foundry. General ventilation should only be employed in conjunction with local exhaust applied to each source of dust.

Floor Moulding

When considering the floor moulding of both large and small castings, it is not practicable to apply exhaust close to many of the sources of dust. Every effort must therefore be made to avoid the production of dust. As mentioned earlier, moulding sand will not form dust if the moisture content does not fall below half of that normally required for moulding in green sand providing that the moisture is evenly distributed throughout the sand. If every effort is made to ensure that tbe moisture content does not fall below this level, the production of dust will be minimised.

The difficulty most frequently encountered is that hot castings lie in the sand and reduce the moisture content of the adjacent sand below the critical level. Hot castings should therefore be removed from the sand as soon as possible to a suitably ventilated cleaning station.

Castings made in dry sand moulds are difficult to treat in this manner. Some form of portable equipment might be considered for use when removing a casting from the mould. The casting should then be transported to a separate section for final cleaning. Any such portable exhaust plant must be arranged to discharge the dust laden air outside the building.

Efficient exhaust could be most economically achieved by the introduction of one or more central knock-out plants and the sand distribution system also exhausted as necessary.

When dealing with the floor moulding of large castings, a substantial improvement in working conditions is possible if moulding positions can be maintained in lines, each served by the suction main of an exhaust system to which flexible branch pipes could be temporarily attached adjacent to the moulding pit where work is in progress. This pit can be temporarily protected by means of portable screens and hoods used in connection with the flexible suction pipe. The hood and pipe positions can also be easily moved to suit the progress of the work, thus affording protection to workers in the immediate vicinity and reducing the spread of dust into the foundry building. The portable equipment can be easily moved from one pit to another.

The main suction ducts will need to be accommodated so that they do not interfere with the use of gantry cranes and may either be on the ground or carried from the main building stanchions.

The alternative system comprises the use of underground ducts to the permanent moulding pits. With this system the exhaust must be applied continuously to all the pits whatever the stage of the work, and this requires a large and costly installation. An independent system for each pit must otherwise be envisaged.

Summary of Dust Control Requirements

1. The most effective dust control is provided by complete enclosure of the knock-out.

2. In side draught systems a long side of the knock-out should be made available for the hood with sufficient space for an efficient form of hood. The side draught system is particularly flexible and suitable for less highly-specialised foundries. In some circumstances hopper exhaust can be used with advantage to supplement side draught.

3. Up draught systems carry the whole of the extracted dust past the breathing zone of the operator and can only offer protection if the operator is in such a position that replacement air diverts the stream away from his breathing zone.

4. Down draught systems can give satisfactory protection from dust and fumes produced by small castings in shallow boxes under the special conditions indicated.

5. General ventilation can do no more than keep down the dust and fume concentration in a foundry and affords little protection to the knock-out operator.

6. Ventilation must not be an after-thought. It is part of the basic lay-out and the plant designer must be prepared to co-operate with the ventilation engineer at an early stage, and to incorporate his recommendations in the plant arrangements.

7. If the moisture level of sand is kept at or above approximately one-half that required for moulding, it will not produce dust in any foundry operation.

APPENDIX X

Local Exhaust at Knock-Out

A Communication from the British Steel Castings Research Association

The main purpose of local exhaust ventilation is to prevent the dust and fumes from entering tbe operator's breathing zone and to prevent them from spreading into the general atmosphere of the shop. Application of a local exhaust system to the knocking-out operation presents one of the most difficult ventilation problems in steel foundries and this is true in particular when large castings are produced. In the range of light and medium weigbt castings there are exhaust knock-outs in steel foundries which show a satisfactory performance. During recent years the British Cast Iron Research Association has carried out an extensive investigation into the theoretical data relating to the design of a knock-out ventilation, which should be of considerable assistance to the designer of such equipment.

It is proposed to review briefly the problem and to draw attention to some installations which proved to be effective in practice.

General Rules of Hood Design

The first and essential requirement for an efficient dust control during the knocking-out operation is that the moulds be brought to a common knock-out point, as there are of course practical difficulties in providing equipment which would control dust created over a large area of the shop floor. If a provision of a local exhaust ventilation is not reasonably practicable, the Iron and Steel Foundry Regulations 1953 require that there must be a high standard of general ventilation.

The upward movement of fumes and dust when knocking out hot castings is due to the rising currents of hot air due to convection. In the case of knocking out cold castings the dispersion of those particles of dust which are heavier than air is caused by turbulent air movement, draughts and general ventilation. Apart from the movement of air due to cross-draughts and general ventilation, the actual process of knocking out is responsible for substantial air currents. The falling sand displaces the air and at the moment of touching the conveyor or the hopper beneath the grid the displacement of air is very rapid and the fine particles of the knocked out sand can easily be picked up by the rising air current displaced by the sand.

Regarding the thermal currents generated when knocking out hot castings, the experimental evidence given by Bamford[28] showed that velocities of up to approximately 400 ft./min. can be expected and tests carried out in practice revealed the velocities of thermal currents to be within the range of 250 to 500 ft./min.

General air movement in foundries was assessed to be of the order of up to 80 ft./min. These air movements are due to the difference of temperature and pressure between the inside and outside of a building and the result of wind, ventilation fans and hot processes carried out inside the building.

The most important factors which should be taken into consideration in the design of knock-out ventilation can be summarized as follows:—

1. As the fine dust particles follow the movement of the air in which they are suspended, the primary conditions for the control of dust is the control of the dust bearing air currents before they reach the operator's breathing zone.
2. In order to achieve the above condition in the most effective and economical way, the knocking-out operation should be enclosed by means of baffles and flanges as far as possible to guide the air flow where it is needed most; the shape of the hood should conform as far as possible to the shape of the area of dust production.
3. An exhaust hood which does not enclose the process should be placed with its opening as close as possible to the point of dust generation.

Methods of Application of Exhaust

There are four main methods of applying local exhaust at a knock-out:

(*a*) fully enclosed knock-out,
(*b*) side-draught into a hood placed close to the knock-out grid,
(*c*) down-draught through the grid,
(*d*) up-draught into an overhead hood.

(*a*) *Fully Enclosed Knock-out*

This is the most effective way of exhausting dust at a knock-out and in addition it requires appreciably lower exhaust volume than any other method. There is no detrimental effect on the constitution of the moulding sand which occurs in the down-draught system and there is less interference in the effectiveness in dust control from the cross-draughts in the shop as is the case in a side or down-draught system.

An example of an enclosed knock-out operating in a steel foundry[27] is shown in Fig. 16. It is of interest to note that the original installation showed several drawbacks, as a result of which inadequate control of dust was obtained because thermal currents caused clouds of dust to escape through the roof. On the basis of the experience gained in practice a number of improvements were introduced which are incorporated in the design shown in Fig. 16. The difficulties encountered with the original plant were as follows:—(i) difficulty in getting the heavier boxes on the shake-out table (roller conveyors were used at both sides of the shake-out and an air hoist on a jib crane); (ii) sand piling up inside and outside the booth and eventually clogging the roller conveyor, due to the hopper being the same size as the shake-out table and knocking-out starting when the box was half on the table; (iii) jamming of multipart boxes and castings on the grid; (iv) the doors having to be kept open during knock-out because the machine had to be left running to facilitate loading, and long hooks had to be used to pull boxes through; (v) the booth distorted very quickly due to the thinness (12 S.W.G.) of the walls. In the modified plant the enclosure was made larger and stronger in order (*a*) to house spring buffer plates along the sides, (*b*) to give ample room for the spillage to find its way through the grids into an enlarged hopper, and (*c*) to allow boxes to be inside the curtains when they contact the vibrating table. The air ducts were housed in the hollow side walls to protect them. The shake-out was serviced by a

hydraulic pusher and turntable for ease in loading. A volume of 7,500 cu. ft./min. was exhausted from the knock-out enclosure.

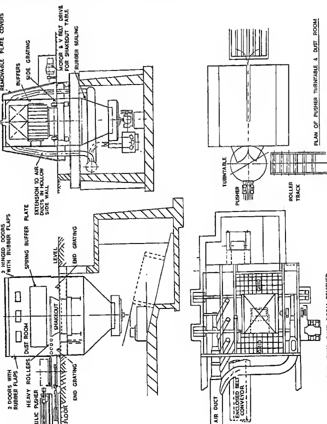


Fig. 16. Enclosed knock-out installed by The Clyde Alloy Steel Co., Ltd., (after Shepherd, Reference 27).

(b) Side-draught

In the side-draught system the exhaust hood is placed close to the shake-out grid, with the suction opening above the level of the top of the mould box. The top of the hood should overhang the shake-out grid as far as possible, and it is advantageous to provide screens on both sides of the hood to reduce the effect of cross-draught.

Velocities of exhaust air flowing over the shake-out grid should be high enough to deflect and entrain the dust bearing thermal currents rising from a

mould, even when this is knocked out at a position on the grid most remote from the exhaust opening. Fig. 17 taken from work carried out by the British Cast Iron Research Association shows mean angle of deflection from the vertical of the thermal currents generated by both the 37 KW and 14 KW ratings of the electric heater in relation to the velocity of surrounding horizontal air movement. Progressively higher air velocity is required to obtain an increased deflection of the thermal currents and according to Bamford a deflection of 60° angle, which requires an air speed of about 200 ft./min., is approaching the maximum deflection that can be obtained with economical exhaust air movement.

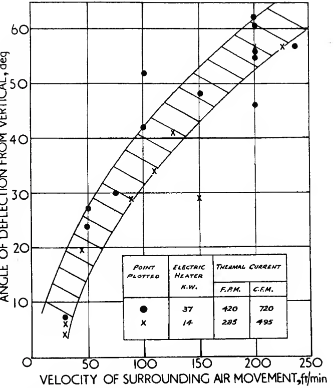


Fig. 17. Mean angle of deflection of thermal currents from the vertical in relation to the velocity of surrounding air movement (after Bamford, Reference 28).

The important point about the side-draught system is that it will operate at a constant exhaust rate independent of the blockage of the shake-out grid by

sand, which often covers the entire grid area and that it exhausts only the fine dust that is airborne above the grid not affecting, therefore, the composition of the knocked out moulding sand.

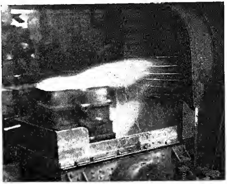


Fig. 18. Knock-out with side-draught at Lake and Elliot Ltd. (after Martin, Reference 76).

An example of a side-draught exhaust which operates successfully in a steel foundry is an installation for boxes 21 in. square, 24 in. high, at Messrs. Lake and Elliot Ltd., Braintree.[76] An exhaust fan, which is supported on two short channels over the pit housing the sand conveyor belt, extracts 17,000 cu. ft./min. and runs at 290 r.p.m. This low speed eliminates all vibrations and reduces maintenance to a minimum. The exhaust system in operation is shown in Fig. 18, which indicates clearly how effectively all fumes and dust are exhausted both from the top and bottom of the mould. In Fig. 19, which shows the air velocity measurements over the grid, it can be seen that in the centre of the grid a velocity of 1,000 ft./min. and on the side of the mould a velocity of 400 ft./min. is obtained. These high velocities of exhaust air over the grid ensure a very good control, not only of thermal currents but also they eliminate the possibility of the dispersion of fumes by even very strong cross-draughts in the shop.

As indicated previously, it is recommended that wherever possible, baffles should be provided around the exhaust opening in order to reduce the volume of air and the horsepower required for an effective dust control. Fig. 20 illustrates the flow of fumes into a hood which overhangs the grid and has baffle plates fitted on both sides. An exhaust rate of 5,000 cu. ft./min. is in operation.

A very effective dust control was achieved in a steel foundry on an 8 ft. by 10 ft. shake-out grid with an exhaust of 24,000 cu. ft./min., by extending the side baffles the full length of the grid. In effect,the shake-out was enclosed on three sides and only the front was left open, and a slot for the slings was provided in the roof for the servicing of the shake-out by an overhead crane.

(c) *Down-draught System*

The performance of the down-draught system depends on the extraction of a sufficient volume of air to provide air velocities high enough to reverse the

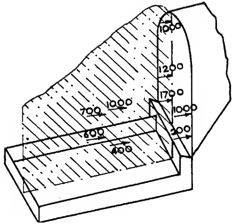


Fig 19. Air velocity measurements (ft./min.) on the knock-out shown in Fig. 3 (after Martin Reference 76).

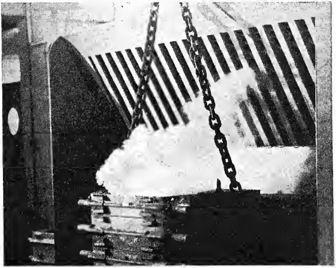


Fig. 20. Flow of fumes into a side-draught exhaust hood with overhang. Exhaust rate 5,000 cu. ft./min.

upward flow of the thermal currents generated by hot moulds and castings before the dust and fumes reach the operator's breathing zone.

This system has the advantage that all four sides of the knock-out are accessible to the operators and for the installation of other equipment, and there is no hindrance to the use of a crane or hoist. On the other hand, a down-draught system has several limitations in its application, which could be summarized as follows:

(a) It cannot be made effective with an economical exhaust rate for boxes exceeding 12 in. in height.

(b) Boxes must be knocked out at grid level.

(c) The size of the knock-out grid should not exceed 16 sq. ft. and the knocking out must be carried out in the centre of the grid, so that the exhaust air flows around the sides of the box.

(d) The blockage of the grid by the box and spilt sand should not exceed 50% of the grid area.

(e) The flow of exhaust air through the falling sand causes a considerable quantity of fine sand particles and clay to be taken into the exhaust ducts, which results in the abrasion of the ventilation equipment and higher maintenance costs.

The down-draught system is being applied mainly in mechanized foundries producing light repetition castings.

(d) Up-draught System

The up-draught into a hood fitted directly over the knock-out grid is comparatively simple to design and operate, but has the disadvantages (*a*) that the operators, who often have to bend over the grid, are breathing the dust laden air moving towards the hood, and (*b*) that it cannot be used when boxes are handled by an overhead crane.

Upwards suction is often employed in completely enclosed shake-outs, in particular for small boxes in mechanized foundries. Fig. 21 gives an example of an upward suction hood partly enclosed.

Compensating Air

The exhaust rates required for the control of dust and fumes during knocking out of large boxes are very high and in the region of 50,000 to 100,000 cu. ft./min. In some conditions, which depend on the ratio of the exhaust volume to the size of the shop in which the knock-out is installed, these high exhaust rates may exceed the number of air changes required by general ventilation of the shop, in particular if some additional local exhaust systems are operating. The result will be excessive loss of the heated air and increased draughts in the shop. To overcome these effects, compensating air can be introduced in the design of the knock-out ventilation, which means that a part of the total exhaust volume is supplied from the outside atmosphere through openings incorporated in the local exhaust ventilation and the remaining part of the total exhaust volume is taken from the shop atmosphere.

An example of a design illustrating this system is shown in Fig. 22. It consists of two side-draught hoods with compensating air, designed for a very large shake-out station. Moulds can be handled by an overhead crane, although the

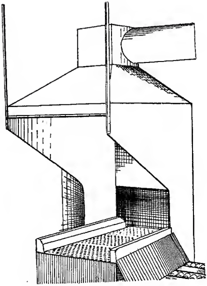


Fig. 21. Up-draught system with a partly enclosed shake-out (after Kane, J. M., "Foundry Ventilation", The Foundry, 1946, LXXIV, February).

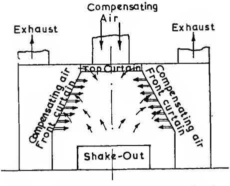


Fig. 22. Two side-draught hoods with compensating air.

shake-out-grid is enclosed on three sides. The total exhaust is 120,000 cu. ft./min., of which 90,000 cu. ft./min. are drawn from outside the building and introduced as air curtains at the open front and top slot of the enclosure.

APPENDIX XI

Dust Control on Portable Fettling Tools Exhausted Fettling Bench

A Communication from the British Steel Castings Research Association

There are four possible methods of applying local exhaust to control dust generated during the operating of pneumatic chisels and portable grinders:

(i) High velocity low volume system (Dustuctor Co. Ltd.).

(ii) Exhausted floor grid.

(iii) Exhausted booth.

(iv) Exhausted fettling bench.

The application of each system depends on many conditions related to the size and shape of the castings fettled, floor space available, ventilation and heating conditions in the shop, etc., but the most important factor is perhaps the size of the castings.

Theoretically, the *high velocity low volume system*, when applied to portable grinders or to pneumatic chisels in the form of "rubber sleeve" or "mason's glove", can be used by the operators working on any size of casting; but steel foundries which have installed this equipment are operating it with varied success.

An *exhausted floor grid* can be effective only under very limited conditions of operating, that is with very small castings, which would not obstruct the air flow into the grid and with the point of dust generation close to the grid.

In dressing light and medium sized castings an *exhausted booth* will give a good dust control providing the work is done close to the booth opening. The application in a foundry of a booth to control dust from portable grinders, when dressing castings of up to 500 lb. in weight, was described by Bolton and Ford[77]. The Association had the opportunity of examining this installation and to carry out some observations on the flow of dust with the aid of the illumination technique for airborne dust. This examination revealed a very effective control of dust generated during grinding. The design of the booth is shown in Fig. 23. An exhaust fan of 4,000 cu. ft./min. capacity, driven by a 2 h.p. motor, provides an air velocity of 125 ft/min. in the booth opening. The heaviest castings are set on a turntable in front of a cabin so that grinding can always be carried out towards the booth opening. The heavy particles are deposited on the floor inside the booth, while the fine dust passes into the exhaust duct. These local exhaust installations ventilate the shop very effectively, as the total exhaust rate is sufficient to change the air in the shop once every 5 minutes.

Exhausted fettling benches, which have been in use for many years can, of course, only be used for light castings. Various designs of exhausted benches are available on the market and none of them can be suitable for every fettling shop. Some features in the design must be made to suit the requirements of a particular shop.

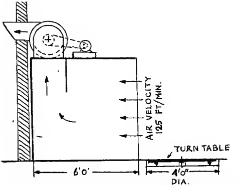


Fig. 23. An exhausted booth for the control of dust generated when dressing castings (after Bolton and Ford, Reference 77).

"K. and L." Fettling Bench

Ottignon and Lawrie[12] described in 1951 their development work and the design of a fettling bench, which is known as the "K. and L." bench. With a working surface of 3 ft. by 2 ft., an exhaust of 600 cu. ft./min. gave an adequate dust control. An air curtain was provided by blowing a volume of 50 cu. ft./min. across the top of the bench and below the level of the operator's face. It was assessed that under these conditions of operating the bench, it was possible to prevent 80% of the dust generated from reaching the operator's breathing zone.

At the Association's York Conference in 1955 the application of this bench was discussed and the modifications made to it at K. & L. Steelfounders and Engineers Ltd. were described[78]. One of the difficulties encountered arose from the fact that in the original design the dust-laden air was discharged through fabric filter pads into the shop atmosphere. These filter pads rapidly became saturated with dust and they had to be replaced twice a day, so the filters were removed altogether and the benches were connected to an exhaust system discharging outside the shop. The other modification was to fit a turntable on the working top so that the castings could be rotated. It was stated that the development work on the design of this bench was still in progress and that for small castings, where a portable grinder and a pneumatic hammer are used, the bench is the best answer at the present time.

"Dustrol" Bench

Tests have been carried out by the Association on an exhausted fettling bench made by Messrs. Newton Collins Ltd., under the registered name of "Dustrol". Observations of the dust clouds were made, using the light beam technique, and a cine-film record was taken when grinding under production conditions.

The general view of the bench is shown in Fig. 24. The table of the bench, which is 4 ft. by 3 ft., is perforated and a turntable is fitted with an indexing

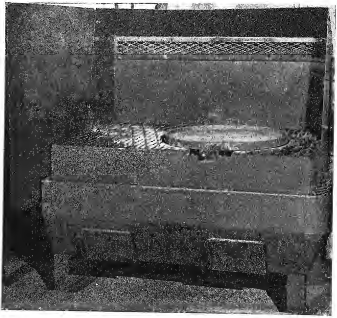


Fig. 24. General view of the "Dustrol" bench.

arrangement to locate in four positions. The back and the sides of the bench are extended above the working table to form a screen.

Approximately 6 in. below the working table a slot is provided along two sides of the bench. This slot is 4 in. wide and is covered with an expanded metal grille. A similar slot covered with a metal grille is located in the back screen 1 ft. 9 in. above the working table.

The perforated table top and the slots are all connected through the chamber formed by the lower part of the bench, and exhausted through a 10 in. dia. duct fitted at the back of the bench. Two slide type doors are provided at the front of the bench for cleaning out.

The manufacturer's specifications allow an exhaust rate of approximately 300 cu. ft./min. per foot run of bench, so that a bench 4 ft. long would require an exhaust of 1,200 cu. ft./min.

Actual measurements (using a Velometer) of the air velocity in the duct connected to the bench have shown that a volume of 2,000 cu. ft./min. was exhausted through the bench. This volume of air is exhausted through the working table and the two slots. Velocities of air flowing into these openings were checked and gave the following distribution of the total exhaust:

TABLE 1

Distribution of the Exhaust Air in the "Dustrol" Bench

Exhaust through:	Average Velocity ft./min.	Exhaust Rate cu. ft./min.
The working table	200	800
The top slot	800	600
The slot along the edge of the working table	750	600
	Total	2,000

One casting on which observations were made was a cast iron bracket 6 in. × 20 in. × 4 in. When grinding the flat face of the casting the primary dust stream (ejected tangentially from the point of grinding) and the secondary dust stream (brought around with the slip stream of the grinding wheel) are near to the exhaust openings and are brought immediately under control (Fig. 25). To facilitate the grinding of edges the operator places the casting so that it overhangs the edge of the table and the main dust stream is directed downwards. It was observed conclusively that under this condition of grinding, the exhaust air flowing in the slot provided along the edge of the table controls the dust very efficiently.

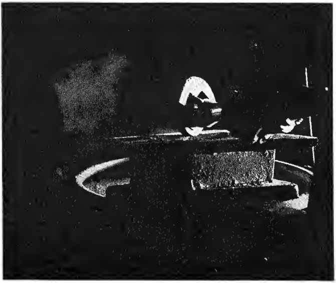


Fig. 25. Control of dust clouds generated when grinding on a "Dustrol" bench.

To test the effectiveness of the exhaust with the point of grinding higher above the working table, observations were made when grinding a steel casting, which was specially selected for this test so that the point of grinding was approximately 12 in. above the table. Dust clouds generated even at this height above the table were directed by the exhaust air into the openings and slots before reaching the operator's breathing zone.

The B.S.C.R.A. Fettling Bench

The B.S.C.R.A. have recently developed a fettling bench which provides control of fine dust as well as some measure of noise reduction. The basic principles of design have been worked out in such a way that they can be applied to both circular and rectangular benches of various sizes. Arrangements

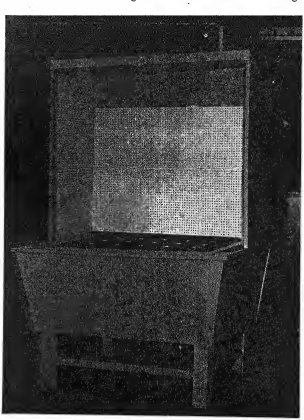


Fig. 26. Prototype of the B.S.C.R.A. fettling bench, which provides dust control and noise reduction.

have been made with two manufacturers for the production of benches to this basic design. A prototype bench is shown in Fig. 26. This has been subjected to trials in a steel foundry over a lengthy period and has proved extremely satisfactory. Comments from operators have been very favourable.

Dust Control. This is provided by means of holes in the bench top and peripheral slots around the top, through which air is exhausted at a rate which varies with the size of the bench, but for a bench with a 3 ft. ×2 ft. working surface the total air exhausted is of the order of 2,000 cu. ft./min. It was demonstrated in preliminary development work that a satisfactory degree of dust control was achieved if, on a rectangular bench, the peripheral slots were extended along the front and both sides of the bench and, on a circular bench, the peripheral slots extended around the front half of the circumference. No slot is required at the rear of the bench. Hoods at the back and sides of the benches control the air flow, ensuring that it largely comes from behind the operator and in a downwards direction. Dust sampling trials made using a thermal precipitator on the chest of an operative show that very effective dust control is achieved during grinding and chipping operations (see Table II). This was supported by visual observations of smoke trails.

TABLE II

Thermal Precipitator Tests on a 3 ft. ×2 ft. Rectangular Bench Exhaust Rate 2,000 cu. ft./min.

Operation	Sampling Period (min.)	No. of Particles per cu. cm in Size Range 0·5–5·0μ
Chipping	15 (exhaust on)	260
Grinding	11 (no exhaust)	3,250
Grinding	12 (exhaust on)	180
General atmosphere of the Shop		295

The holes in the bench top should be 1–1½ in. internal diameter arranged in a pattern with 6 in. between the centres of the holes. The extraction velocity through the holes should be 25 cu. ft./min. per hole. The width of the peripheral duct is 3 in. and the extraction rate through this duct should be 200 cu. ft./min. per foot run for a rectangular bench and 350 cu. ft./min. per foot run for a circular bench.

When castings are manipulated on the bench top it is quite convenient for them to be fettled against an angle iron support located by pins dropped into two of the holes in the bench top. This does not lead to any loss of dust control.

Noise Control. The sources of noise during fettling are varied and include:

(*a*) the fettling tool exhaust,

(*b*) the impact of the hammer or wheel on the casting,

(*c*) resonance of the casting and vibration against its support,

(*d*) transmission of vibration from the casting support to surrounding structures,

(*e*) reflection of direct noise by the hood controlling the air flow.

Items (*a*) and (*b*) are in some ways unavoidable, although work is in hand which it is hoped will lead to some means of minimizing exhaust noise from fettling tools.

Items (*c*) and (*d*) depend chiefly on the mass of the casting support. In the B.S.C.R.A. bench a massive noise-absorbent structure has been obtained by the use of 6 in. thick concrete slabs topped by 2 in. hardwood planking.

The build-up of reflected noise has been obviated by lining the bench hoods with acoustic tiling having a high noise absorption characteristic at the peak frequencies occurring during fettling.

Table III gives the results of noise measurements made during tests in which a casting was chipped under standard conditions on various types of support. It will be seen that the noise pressure level, when chipping was conducted on the B.S.C.R.A. bench, was 47% less than that generated during the identical operation when the casting was supported on wooden planks.

TABLE III

Comparative Noise Tests on Casting Supports (Chipping only)

Work Support	Noise Pressure Level (dB)	Reduction %
Wooden Planks	101–103	—
Iron Grid supported at ends only	100–102	10·4
Iron Grid on Wooden Planks	99–101	20·6
Prototype Bench (unlined hood)	98– 99	33·1
Prototype Bench (lined hood)	96– 97	47·2

Conclusions

The above experiments have shown that the B.S.C.R.A. bench provides highly efficient control of dust generated during the fettling of light castings and, at the same time, provides a substantial reduction of the noise pressure level. Practical fettling shop trials have also proved satisfactory and arrangements have been made for the commercial production of benches of this basic design.

Acknowledgements

The Association's thanks are due to Messrs. K. & L. Steelfounders & Engineers Ltd., for information on the development of the "K. & L." bench; to Morris Motors Ltd., Wellingborough Foundry, for affording facilities for observations on their exhausted booth, and to Newton Collins Ltd. and Bradley & Foster Ltd. for affording facilities for testing the "Dustrol" fettling bench.

Dust Control on Stand Grinding Machines

A Communication from the British Steel Castings Research Association

The application of a high intensity beam of light for producing what is known as the Tyndall effect and the use of cine-film photography for the observations and recording of moving dust clouds, which are normally invisible, was described in 1951 in a paper by Ottignon and Lawrie[12]. One of their observations was made on a double-ended stand grinder fitted with a local exhaust ventilation system, which was shown to be ineffective because an appreciable amount of dust followed the wheel around and was dispersed into the operator's breathing zone from the space between the top of the guard and the top of the wheel. No mention was made of the exhaust rate applied to the wheel guard.

During 1951 the Association began experimental work in this field with the co-operation of the Ventilation Committee of the Foundry Trades' Equipment and Supplies Association, who made available for experimental purposes a series of stand grinding machines fitted with 24 in. dia. wheels running at the peripheral speed of 9,000 ft./min.[50].

Preliminary observations at the Association's Dust Research Station were conducted using perspex and covers fitted to the grinding machines, by means of which it was possible to observe under appropriate conditions of illumination, the flow of dust-laden air inside the machine cowling. These observations revealed that the dust stream adhered closely to the grinding wheel periphery, particularly during the first 90° of travel from the point of generation and that the stream of exhaust air which was drawn into the cowling through the gap beneath the work-rest passed along the dust stream without causing any appreciable disturbance to it, Fig. 27*a*. By covering the gap beneath the work-rest, the exhaust air entering the cowling was brought closer to the dust stream

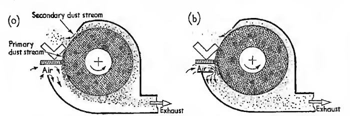


Fig. 27. Diagrammatic presentation of the effect of the exhaust air on the dust stream inside the cowling when the gap beneath the work rest is (*a*) fully open, and (*b*) restricted.

and it was observed that the dust stream became dispersed inside the cowling and a much larger proportion of dust was drawn into the exhaust duct, Fig. 27*b*. As a result, a considerably reduced quantity of dust escaped to the atmosphere at the point where the grinding wheel emerges from the cowl in front of the operator. In the initial stages of experiments the closing of the

gap below the work-rest was achieved by covering the mouth of the cowling with a sheet of metal. Under production conditions it is essential that this gap should remain closed when the work-rest is adjusted because of the wheel wear. The manufacturers of grinding machines in collaboration which the Research Association have designed and made work-rests which meet this requirement satisfactorily, and examples of these can be seen in Fig. 28 and Fig. 31.

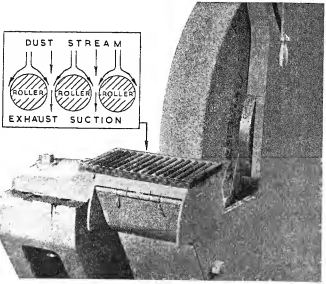


Fig. 28. Roller top work-rest: inset shows streamline design of air flow.

Experimental work at the Dust Research Station has shown also that the work-rest when in its normally used position, i.e. approximately ¼ in. from the periphery of the grinding wheel, acts as a stripping plate to the stream of dust coming from the point of its generation. It will be appreciated that the stripping effect by the work-rest increases as the distance between the point of grinding and the work-rest increases. For an effective dust control on the machine it is essential that all the dust stream generated by grinding enters the machine cowling and for this purpose it is necessary to perforate the work-rest, thus reducing its stripping effect on the primary dust stream.

Various designs of perforations, including slots cut parallel or at right angles to the wheel face and round holes of various size at different spacings were tested. If the perforations are too small they become clogged, and if too large they interfere with the movement of the casting. A roller top work-rest provides the best conditions for an effective control of the primary dust stream. The roller top work-rest was developed as a result of observations carried out in

a fettling shop of a steel foundry. Due to the shape and size of casting, the point of contact with the grinding wheel when grinding some parts of it was up to 9 in. (approximately) above the work-rest. Although the work-rest was provided with several rows of $\frac{1}{4}$ in. diameter holes, the area of the remaining flat surface of the work-rest was large enough to deflect a substantial volume of the primary dust stream. The dust spreads sideways and, due to its high initial velocity, it travelled for several feet as a well-defined stream before it dispersed into the general atmosphere. Following these observations a work-rest was designed in which the perforated top was replaced by $\frac{1}{2}$ in. diameter rollers spaced so as to leave a row of parallel slots $\frac{1}{8}$ in. wide. It will be apparent from a consideration of the cross-section of this design that virtually the whole top surface of the work-rest is subjected to suction and that the "slots" are of streamlined design, Fig. 28. In addition the slots are self-cleaning. Laboratory and production trials indicated that the new roller top work-rest contributed to a satisfactory control of dust when grinding at any reasonable position above the work-rest.

It is realized, however, that under some conditions of operating the machine, for example, when a push-bar is used, holes must be provided in the work-rest to locate the bar, and that the design of perforations in the work-rest will have to be adapted to the conditions of operation. A perforated work-rest which had proved to be very effective under practical foundry conditions is shown in Fig. 29.

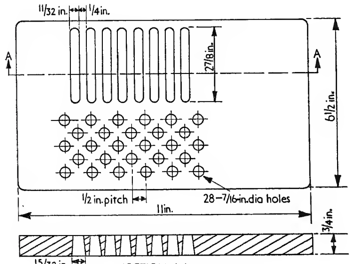


Fig. 29. Arrangement of perforations in work-rest.

Exhaust Volume and Dust Control

Observations have shown that an exhaust of 900 cu. ft./min. (at 2½ in. S.W.G.) provides a satisfactory control of very heavy dust clouds generated not only when grinding iron or steel castings with a thick layer of adhering sand (castings not shot blasted), but also when grinding refractory bricks[57]. The effect of the exhaust can be judged from the photographs shown in Fig. 30. The photograph on the left (*a*) demonstrates conditions when the exhaust is not operating and the primary dust stream is partially deflected by the work-rest, while the secondary dust stream emerges at the top of the hood, contaminating the operator's breathing zone. With the exhaust in operation the whole of the primary dust stream enters the hood through the perforations in the work-rest, and no dust can be seen escaping at the top of the hood. Fig. 30(b).

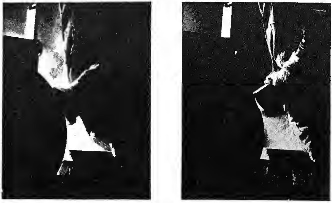


Fig. 30. Showing dust clouds when grinding refractory brick on a machine of the type shown in Fig. 5: (*a*) no exhaust; (*b*) exhaust of 900 cu. ft./min. in operation.

With the aid of smoke generating pellets it has been shown that the exhaust air flows into the hood in the vicinity of the work-rest, through the perforations in the work-rest and through the slots on both sides of the wheel in the upper part of the hood.

Following extensive experimental work and the successful design of the exhaust system for 24 inch machines, a series of tests was made to check the effectiveness of the B.S.C.R.A. exhaust system on different sizes of high speed (9,000 ft./min. peripheral velocity) grinding machines ranging from a 14 inch diameter wheel to a 30 inch diameter wheel. Assessment of the dust control achieved was made by dust counts of samples of atmospheric dust collected by thermal precipitators. Dust concentration in the operator's breathing zone was assessed by taking samples, when grinding, with a thermal precipitator mounted on the operator's chest. Simultaneously thermal precipitator samples of the general atmosphere were taken at a position remote from air currents caused by the grinding wheel or exhaust. The results of these tests and the exhaust

rates applied to different machines are shown in Table I. The static pressure at the machines varied for different sizes of machines between 2½ inch to 3¼ inch water gauge.

TABLE I

Results of Dust Counts on High Speed Stand Grinding Machines of different sizes fitted with the B.S.C.R.A. Exhaust System

Grinding Machine		Dust concentration (0·5 to 5 micron particle size range)	
Diameter of wheel, inch	Exhaust rate cu. ft./min.	Operator's breathing zone. Particles per cu. cm.	General atmosphere. Particles per cu. cm.
14	500	850	800
16	750	800	850
18	750	850	800
20	900	800	800
30	1,000	850	800

To obtain an indication of the density of dust clouds generated during these tests, a sample was taken in the operator's breathing zone with *no* exhaust in operation. After only 3 minutes of grinding the sample collected showed 3,900 particles per cu. cm. in the 0·5–5·0 micron particle size range.

Conclusions

The main features of the B.S.C.R.A. exhaust hood for an improved dust control can be summarized as follows (see Fig. 31):

1. The underside of the work-rest is closed on three sides, only the side nearest the wheel is left open.
2. The work-rest is perforated.
3. A top flap, which is easily adjustable to wheel wear, is fitted.
4. The gaps between the sides of the hood and the wheel are left open above the centre line of the wheel, but the gaps below the centre line are covered.

From the results of tests, using thermal precipitator samplers and the illumination technique, it can be concluded that a good dust control was obtained on a range of stand grinding machines fitted with the B.S.C.R.A. exhaust system and with the following exhaust rates.

Grinding wheel, dia., in.	30	24	20	18	16	14
Exhaust rate, cu. ft./min.	1,000	900	900	750	750	500

The thermal precipitator samples showed that, for all the machines tested, the dust concentration in the operator's breathing zone was the same, within the limits of experimental error, as in the general atmosphere in the shop.

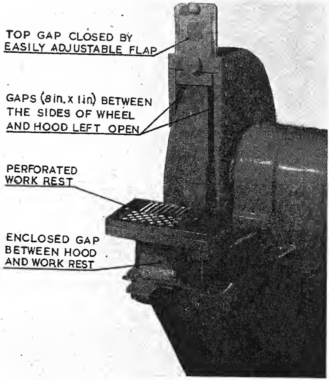


Fig. 31. Showing the main features of the B.S.C.R.A. exhaust hood. Grinding wheel 24 in. by 2½ in., peripheral speed 9,000 ft./min., exhaust rate 900 cu. ft./min. per wheel.

Machines incorporating the B.S.C.R.A. exhaust system are now being manufactured by three firms in Great Britain.

Acknowledgements

The British Steel Castings Research Association acknowledges the help which it has received from the British Steel Founders' Association in providing financial support for the work on this subject and the assistance received from members of the Foundry Trades' Equipment & Supplies Association in the provision of grinding machines for test purposes.

The External and Combined Dust Control Systems for Pedestal Grinders

The External System

1. The rapid dust estimation method[6] and the observation and cinematography of dust clouds[12] showed that conventional local exhaust ventilating systems fitted to stand grinders were not always as successful as had been supposed. The original work [12] was done on a 24 in. diameter wheel running at a peripheral velocity of 9,000 ft. per minute, and it was found that large quantities of fine dust which had been generated by the grinding operation followed the wheel round and were ejected at high velocity from the guard opening at the top of the wheel. Most of the particles which formed this dust cloud, were less than 5 microns in diameter, and were therefore within the respirable size range and in consequence were invisible in ordinary lighting conditions. This dust stream had not therefore been seen until it was observed and photographed by the method developed for this work[12]. When these early observations had been completed, the Foundry Atmospheres Committee decided that the matter should be investigated more fully and that as the early work had been done on a 24 in. diameter wheel, it was desirable to explore the effects on a smaller wheel running at a lower velocity. As a result of this decision, the work was undertaken for the Foundry Atmospheres Committee by Mr. W. H. White of the British Cast Iron Research Association and Mr. W. B. Lawrie, a member of our Committee, and the original work was published in 1952[58] when it had been discovered that the smaller and slower wheel exhibited aerodynamic characteristics which were similar to those shown by the larger one.

2. The experimental work was commenced on a 14 in. $\times 2\frac{1}{2}$ in. wheel rotating at 1,400 revolutions per minute with a peripheral velocity of 5,000 ft. per minute, and fitted with a normal type of dust extraction unit. The early work was directed towards the elucidation of the aerodynamics of the system and the workers explored the zone of influence of the rotating wheel by means of the observation and photographic method[12] as well as by the measurement of air velocities with a Metropolitan Vickers Velometer. The observations were made both with and without the conventional local exhaust ventilating system in order to estimate the effects of the wheel itself and also the effect of the ventilating system on it.

3. Early films showed[58] that the dust distribution from the wheel conformed to the general pattern discovered on the 24 in. diameter wheel[12], and it was concluded that the dust streams indicated in Figure 32, would have to be collected if the local exhaust system were to be efficient[58]. The work also showed that the primary dust stream which flowed down the wheel face at velocities up to 3,000 ft per minute was not being reversed by the conventional local exhaust system because of its high velocity. It became clear that it could be more easily controlled, after decelerating outside the wheel hood, by means of relatively low volume air streams, provided that they moved at a sufficiently high velocity.

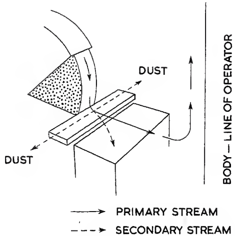


Fig. 32. Dust streams requiring collection if the extraction system is to be efficient.

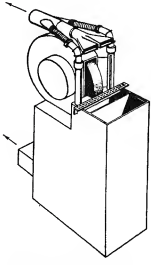


Fig. 33. Prototype fitted with nozzles.

The two investigators proceeded therefore with the design of an exhaust system which was to be external to the wheel cowl[58].

4. The conventional exhaust system was completely removed from this small wheel, and the dust produced by grinding was allowed to leave the wheel cowl before being collected. The new local exhaust ventilation system that was developed operated therefore externally to the cowl so that it became known as "the external dust control system". The final prototype is shown in Figure 33. In this machine the primary dust stream was collected through the nozzle mounted above the wheel hood, the secondary stream which flows along the work-rest was collected through the two vertical pipes placed one on each side of the wheel, and the hopper in front of the rest served to collect the heavier particles which were projected downwards from the work. The ventilating air entered the top nozzle at a velocity of 5,000 ft. per minute, and entered the side ducts at a velocity of 3,500 ft. per minute, while the velocity at the rim of the small hopper was 1,000 ft. per minute. The total air volume used on this machine was about 450 cu. ft. per minute.

5. The development work was based on the movement of the dust clouds which were recorded on a 35 millimetre cinematograph film and the efficiency of the new external dust control system can be seen from Figures 34 and 35, which are reproduced from the original film negative.

6. The two research workers drew the following conclusions[58]:

"(1) It has been shown that the phenomena found on the grinding wheel running with a peripheral velocity of 9,000 ft. per minute which were described in a previous paper[12] also appear on a wheel running at a peripheral velocity of 5,000 ft. per minute.

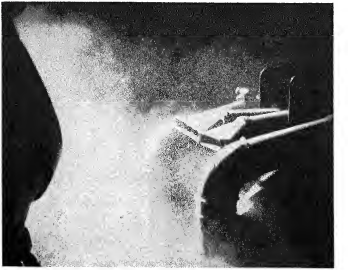


Fig. 34. Grinding grey iron without local exhaust ventilation.

Fig. 35. The external system with the exhaust fully operative. Dust control when grinding grey iron.

(2) The primary dust stream, which flows down the face of the rotating wheel and sundry secondary air streams which develop therefrom have been photographed by means of a cinematograph camera.

(3) The necessity for dust-tight dust collectors has been shown by photographs of a dust cloud of about 2,000 particles per cubic centimetre which was found to be leaking continuously from a collector unit, which was under pressure from the fan.

(4) It has been found that in cases where the dust moves in well-defined streams, dust samples taken in standard conditions when the dust is invisible may give erratic results. It appears that these variations in the results are often due to the fact that the instrument may fail completely to sample the main dust stream and may be collecting from a much cleaner air stream moving alongside the dust stream. It appears, therefore, that visual dust observations are desirable to supplement dust counts.

(5) Observations have shown that the dust control achieved by the new external exhaust system is superior to that obtained by the conventional method of ventilation in the experimental conditions imposed. Even when the dust clouds momentarily burst through the high velocity air curtains, the dust was quickly recaptured by the system.

(6) Observations have suggested that nozzles are at least as good as, if not better than, the long extraction arms.

(7) Thermal precipitator dust counts have shown that the new system is capable of controlling dust clouds, so that the breathing zone concentration remains below about 750 particles per cubic centimetre, even when the dust cloud generated is of the order of 60,000 particles per cubic centimetre. In these conditions of gross overload, the average breathing zone dust concentrations lay between 400 and 500 particles per cubic centimetre."

The Combined Dust Control System

7. After the external dust control system[58] had been fitted to a 14 in. diameter wheel running at a peripheral speed of 5,000 ft. per minute, the Foundry Atmospheres Committee decided that the aerodynamics of a 24 in. diameter wheel with a peripheral velocity of 9,000 ft. per minute should be explored. Once again the investigations were undertaken by Mr. W. H. White, a member of the British Cast Iron Research Association, and Mr. W. B. Lawrie, a member of our Committee, and the work was done in the laboratories of the British Cast Iron Research Association[59].

8. In the first instance the external system, which had been applied on the 14 in. diameter wheel, was adapted to the 24 in. diameter wheel as it stood[58]. The standard dust collecting box fitted to the larger wheel was, however, too small to release the pressure generated by the running wheel. In consequence, the dust was blown out of the collecting box and the external system was overloaded to such an extent that it did not give adequate dust control. It was evident that the pressure in the collecting box must be relieved and it was decided to do this by connecting it to the fan in the conventional manner. This resulted in the combined dust control system which is shown in Figure 36. The exhaust duct at the back of the dust collecting box releases the air pressure set up by the fan effect of the wheel and also extracts some of the dust. The external part of the system applied over the top and down each side of the wheel collects the dust which either leaves or fails to enter the wheel guard. In addition to these arrangements, the work-rest was perforated and mounted directly on top of the collecting box. This was done so that dust could be collected through the perforated rest if the work was small enough to leave part of it uncovered.

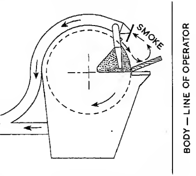


Fig. 36. Diagrammatic sketch of the combined exhaust system.

It was found, however, that the system would still work satisfactorily even if the perforated rest were covered, because in these circumstances the external part of the system took a larger proportion of the dust.

9. The system was tested in laboratory conditions using a 24 in. diameter wheel and the 16 in. diameter wheel. The smaller wheel was used in order to estimate the effects of wheel wear on the efficiency of the ventilating system. Neither the observation technique nor the thermal precipitator dust counts showed any significant difference in dust concentration (at the breathing level of the operator) between operating conditions and general atmospheric conditions before commencing work. This indicated the efficiency of the prototype and the conclusion was valid both on a new wheel of full diameter and on the worn wheel which was only 16 in. in diameter[59]. The combined system in the conditions obtaining at the time was therefore controlling all the dust generated by the grinding process. The thermal precipitator counts were not incinerated in order to retain all the dust produced and they were counted in standard conditions on an optical microscope counting all particles down to the limit of visibility in light field illumination.

One further point of interest emerged from the test. Grinding machines are normally fitted with an adjustable flap at the guard opening at the top of the wheel. This flap is adjustable so that it can be lowered as the wheel wears, in order to maintain a minimum gap between the guard and the wheel top. In practice, however, this adjustment is not always made as carefully as it should be and in the conventional local exhaust system it may affect the efficiency of the dust control. The tests on the combined exhaust system, however, showed

Fig. 37. Grinding wood showing good smoke control.

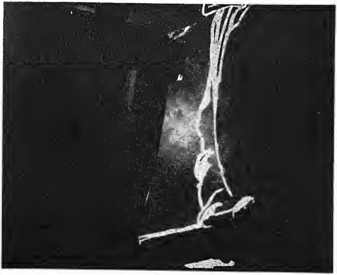


Fig. 38. Combined system with worn 16 in. dia. wheel in use. Good dust control in spite of large gap over wheel top.

that the magnitude of the gap between the wheel top and the guard did not influence the efficiency of the dust control. Even when the gap was deliberately increased to $4\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in., by using a 16 in. diameter wheel, the experimental system still retained control of the dust.

Full experimental details have already been published[59]. Figure 37, however, shows that the smoke produced by grinding wood can be controlled by the system. This observation may not be applicable to the dust produced when grinding metal, but it serves to indicate the efficiency of the system on very small particles. Figure 38 shows the combined system with the worn 16 in. diameter wheel being used to grind grey iron. The dust cloud is being cut off at the level of the top nozzle well below the breathing zone of the operator, and the system has good control over the dust in spite of the large gap between the wheel top and the guard.

10. The work on the 24 in. diameter wheel led the authors of the original paper[59] to the following conclusions:

"1. The combined exhaust system gave very good dust control when the machine was fitted with a 24 in. diameter wheel.

2. The gap between the wheel top and the guard did not influence the efficiency of the dust control. Even when this gap was increased to $4\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in. by using a 16 in. diameter wheel, the experimental system still retained control of the dust.

3. Neither the observation technique nor the thermal precipitator counts showed any measurable difference in dust concentration (at the breathing level of the operator) between operating conditions and general atmospheric conditions before commencing work. This conclusion, which is valid for both the 24 in. diameter wheel and the 16 in. diameter wheel, indicates the efficiency of the prototype operating under the experimental conditions imposed during testing"[59].

11. The original research work was published in 1953, after which the system was developed for industrial use. It has been used in the ordinary day-to-day conditions of foundry dressing shops over a period of some years and it has been shown that the experimental results can be achieved in the ordinary operating conditions of the normal dressing shop.

Dust Control on Swing Frame Grinding Machines

A Communication from the British Steel Castings Research Association

GENERAL CONSIDERATIONS

Introduction

A series of observations was made, both in the B.S.C.R.A. Dust Research Station and under industrial conditions, of the dust flow characteristics of various types and sizes of swing frame grinding machines as a preliminary to original experimental work in this field. There are three main types of machine commonly used in the steelfounding industry:

1. *Standard design* machine in which the grinding wheel is in-line with the main frame, the operator standing in front of the machine and controlling it by what are popularly known as "cow-horn" handles, Fig. 39.
2. *Astride design* machine, which is similar to the standard unit in so far as its grinding wheel is in-line with its main frame, but with the modification that the operator stands astride the wheel, the machine being controlled by a handle that is parallel to the wheel axis. The operator's back is towards the motor of the machine and his head is above the grinding wheel itself, Fig. 40.
3. *Transverse wheel design*, in which the grinding wheel is mounted at right angles to the supporting beam, while the operator stands in front of the unit in the position similar to that in the case of type 1, Fig. 41.

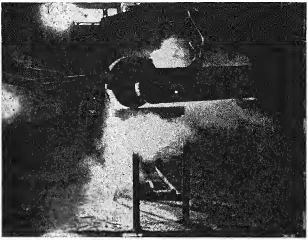
Dust and Air Flow Characteristics

Throughout these studies the observations of dust flow and the detection of dust were based upon the Tyndall beam method of illuminating airborne dust, which enables the dust of respirable size range to be seen and photographed. Cinematograph film records were made throughout the experimental work.

(*a*) *Dust Flow Pattern*

These various types of swing frame grinder show the same characteristic pattern of dust flow, consisting of a primary stream of dust ejected tangentially from the point of its generation and a secondary stream of dust emerging from the wheel guard.

The primary dust stream consists of particles of a very wide range of sizes. Large particles are of no importance from the point of view of the health hazard, but their influence on the flow of fine dust has to be considered. When grinding different materials, i.e. wood, steel castings and rusty pig iron, it became evident that the nature of the material being ground has an influence upon the behaviour of the primary dust stream. Where a proportion of relatively large particles is produced by the grinding operation, these particles, due to the kinetic energy imparted to them on their formation and release, follow a straight path tangential to the wheel for a considerable distance (several feet), and they, in turn, induce some of the fine dust to follow in the same path and to remain in the primary stream.



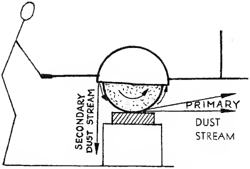
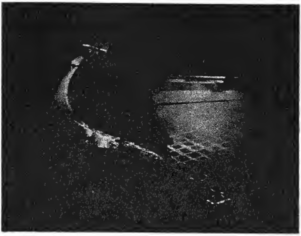


Fig. 39. Swing Frame Grinder of "Standard" design. Grinding Wood.



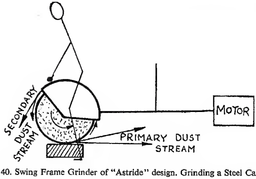
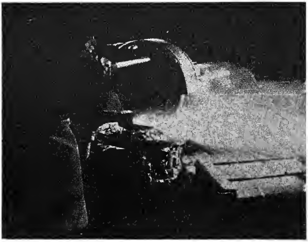


Fig. 40. Swing Frame Grinder of "Astride" design. Grinding a Steel Casting.



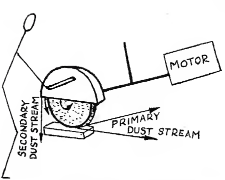


Fig. 41. Swing Frame Grinder of "Transverse" design. Grinding a Steel Casting with excessive adherence of Sand.

The secondary dust stream is brought around with the slip-stream produced by the rotating grinding wheel, is discharged into the general atmosphere and may reach the operator's breathing zone. Whether it reaches the operator's breathing zone as a cloud of high concentration depends upon the position of the operator (in particular upon the position of his head), in relation to this stream of dust, and upon the contour of the casting that is being ground. The effect of the shape or contour of the casting being ground is evident, as this stream, on leaving the hood, is directed downwards, and, depending upon the position of the grinding machine relative to the casting, will either continue unobstructed until it reaches the floor or will be deflected and spread sideways and, in many cases, partially upwards, depending upon the configuration of the obstruction, i.e. the casting or the bench, which it may meet.

(*b*) *Air Flow Pattern*

The velocities of air streams produced by a 16 in. dia. grinding wheel when rotating with a peripheral velocity of 9,000 ft./min. are shown in Fig. 42.

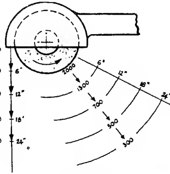


Fig. 42. Velocities of air flow (ft./min.) produced by a 16 in. dia. grinding wheel, with 9,000 ft./min. peripheral velocity.

LOCAL EXHAUST SYSTEMS

The Association has studied the following five methods of applying local exhaust ventilation:

External Exhaust Systems

1. *Down-Draught,* in which the grinding operation is conducted over or adjacent to a floor grid through which dust laden air is extracted.
2. *Booth* (side-draught), in which the swing frame grinder operates in front of a booth that is exhausted by means of a fan.

Integral Exhaust Systems, in which the local exhaust is embodied in the

swing frame grinder unit itself and a flexible pipe connects it with an exhaust fan

3. The English Steel Corporation Ltd. Exhaust system.

   While each of these methods was subjected to critical examination with the object of assessing its relative efficiency and advantages, the main experimental work of the Association was concentrated on designing an exhaust system integral with the swing frame grinder machine and resulted in the development of

4. The B.S.C.R.A. integral exhaust system.

   Further experimental work led to a modified application of the above systems and led to the development of an original method, which is described later as

5. The B.S.C.R.A. combined booth and integral exhaust system.

1. *Down-draught Exhaust System*

Observations of this system, Fig. 43, were carried out in a steel foundry fettling shop, where this installation has been in operation for several years.

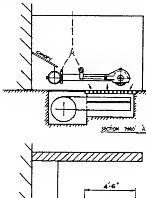


Fig. 43. Down-draught exhaust system.

The dust control is obtained by enclosing the machine and the working area on three sides and by providing local exhaust ventilation through a floor

grid 4 ft. 6 in. long and 3 ft. wide. This grid is placed over a pit fitted with an exhaust duct through which 5,000 cu. ft./min. of air is drawn into a dust collector. The addition of a canopy-plate on the rear wall assists the dust control by deflecting the primary stream towards the grid.

The castings that are ground are mainly flat and the dust clouds generated are close to the grid and are within the influence of the currents of air flowing into it.

The primary dust stream, when thrown directly towards the grid openings is brought under control immediately.

The effectiveness in the control of the secondary dust stream depends on the position of the casting on the grid.

Should a casting cover the grid openings in front of the grinding wheel, then the secondary dust stream will spread sideways and some of it might escape the exhaust system.

Providing there is free passage for the dust stream through the grid into the exhaust duct, the control of dust is satisfactory.

The area of the grid should be in excess of the largest casting to be ground and the point of grinding should be close to the grid for effective dust control.

2. *Booth (Side-Draught) Exhaust System*

The principle of the booth exhaust system, Fig. 44, is to enclose the work area as far as possible by a booth coupled to an exhaust fan to create a current of air passing the operator.

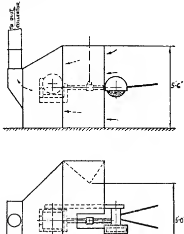


Fig. 44. Booth (side draught) exhaust system.

The booth, which was used in the experimental work at the B.S.C.R.A. Dust Research Station, had an opening 5 ft. wide and 5 ft. 6 in. high. For easy adjustment of the exhaust air, a damper was fitted in the duct connecting the booth to a fan of 6,000 cu. ft./min. capacity. A swing frame grinder with a 16 in. dia. wheel running at 9,000 ft./min. peripheral velocity was used.

During grinding the primary dust stream is thrown directly to the rear of the booth and is immediately brought under control even with an exhaust volume as low as 1,500 cu. ft./min. in operation.

But the effectiveness in the control of the secondary dust stream depends on various factors, such as the velocity of exhaust air in the booth opening, the fan capacity, the distance of the grinding wheel from the booth opening and the obstruction to the air and dust flow by the casting or bench. If a casting or a work table projects in front of the grinding wheel, the secondary dust stream will be deflected sideways and upwards. It has been observed that even when grinding in a booth opening and with an exhaust rate of 6,000 cu. ft./min. in operation, which gives a velocity of exhaust air of approximately 250 ft./min. in the vicinity of the grinding wheel, dust clouds of high concentration may reach the operator's breathing zone.

If the conditions of grinding are such that the secondary dust stream travels unobstructed to the floor, its control will depend not only on the velocity of the exhaust air, but also on the distance of the grinding point above the floor and the construction of the work table. Observations have shown that with the point of grinding 2 ft. above the floor a considerable volume of dust was deflected by the floor and spread to a distance of several feet from the grinding position and dispersed in the general atmosphere of the shop. These conditions occurred even with an exhaust rate of 6,000 cu. ft./min. and when the front

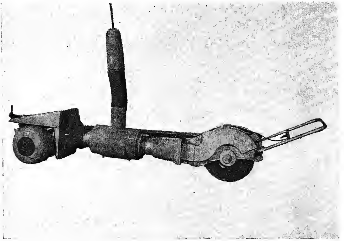


Fig. 45. General View of the E.S.C.—type 20 in. dia. Swing-Frame Grinding Machine.

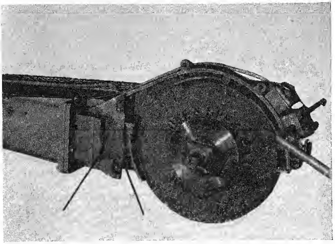


Fig. 46. The E.S.C. machine head with the side of the cowling removed to show the position of baffles and exhaust openings.

of the work table was left open. In order to simulate the conditions when grinding a large casting standing on the floor, the front of the work table was covered. As could be expected, the dust clouds deflected away from the booth opening were more pronounced and more dust escaped into the shop atmosphere.

As a next step in experimental work the height of the work table was increased from 2 ft. to 3 ft. above the floor level, so that the secondary dust stream had a longer distance to travel and, therefore, a lower velocity (approximately 500 ft. per min.) when reaching the floor. An exhaust of 6,000 cu. ft./min. was required to direct the dust stream into the booth opening before it reached the floor and to control it satisfactorily.

3. *The E.S.C. Integral Exhaust System*

The general principle of the design developed by the English Steel Corporation, Figs. 45 and 46, is to control the dust generated by grinding, by exhausting it through the hollow frame or beam of the machine itself. In order to achieve this the primary dust stream is exhausted directly into an opening in the machine frame immediately to the rear of the grinding wheel. To control the secondary dust stream entrained in the peripheral slip-stream of the wheel, there are three adjustable stripping plates or baffles incorporated in the wheel guard. These baffles are coupled so as to permit simultaneous adjustment by the operator of their position in relation to the wheel periphery. Adjustment is facilitated by the fitting of a rattling device which comes into operation as the adjustable baffles contact the wheel periphery.

The dust deflected or stripped by these adjustable baffles is then extracted in a direction parallel to the axis of the grinding wheel into a chamber incorpor-

ated in the side of the wheel cowling. This chamber is, in turn, connected to the main exhaust duct formed by the hollow frame or beam of the machine.

Incorporated in the machine's hollow beam at its mid-section is an expansion chamber for the purpose of allowing large dust and grinding particles to settle, while the main stream is carried upwards into the flexible pipe to the dust collection unit. The expansion chamber is provided with a removable plate to permit cleaning.

Observations were carried out at the B.S.C.R.A. Dust Research Station on a 20 in. dia. wheel machine with an exhaust of 900 cu. ft./min. at $7\frac{1}{2}$ in. w.g. static pressure. These trials have shown that the machine provides an effective means of controlling dust generated during grinding and of reducing to a very considerable extent the contamination of the general atmosphere of the shop in which the machine is operated. The machine does not attempt to control the large particles (sparks) arising from the grinding operations.

4. *The B.S.C.R.A. Integral Exhaust System*

The object of the B.S.C.R.A. work was to develop a device or modification that can be applied to existing as well as to new swing frame grinding machines in foundries, preferably involving a minimum cost and a maximum of simplicity.

(*a*) *Equipment and Stages of Development*

The experimental work was conducted with a "standard" machine, with grinding wheel 16 in. dia., $2\frac{1}{2}$ in. wide, driven by a $7\frac{1}{2}$ h.p. electric motor giving a peripheral velocity of 9,000 ft./min.

The various experimental attachments to the grinding machines were connected in each case through a $5\frac{1}{2}$ in. bore flexible pipe to a paddle-blade fan and cyclone unit. The fan used has a capacity of 1,500 cu. ft./min. at a pressure of $7\frac{1}{2}$ in. w.g.; its speed was 2,850 r.p.m., power 4 b.h.p. and outlet velocity 2,739 ft./min.

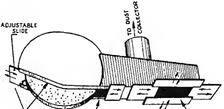


Fig. 47. Development Stage I of experimental attachment for dust control on swing frame grinder. Note the sliding covers on the underside of the attachment.

In the first stage of the experimental work the following alterations to the wheel guard were made, see Fig. 47:

(i) Closing the gap between the sides of the wheel and the hood.

(ii) Closing the opening at the front of the hood with a plate adjustable to the wheel wear.

(iii) Fitting an attachment, which formed an extension to the back of the hood. This extension built in the shape of a box had two intake-openings in the underside. The intake nearest to the wheel (which is an extension of the slot accommodating the grinding wheel) admits the slip-stream that carries the dust forming the secondary dust stream. The second intake was placed further away from the wheel to bring under control the fine dust entrained in the primary stream. Both intakes were provided with sliding covers to allow easy adjustment to the size of the openings for experimental purposes.

(iv) Removing a portion of the back plate of the wheel hood, to produce a continuous internal cavity within the original hood and the "box" attachment. The orthodox hood was thus brought within the influence of the exhaust system.

The following notes summarize the observations made during trials carried out to determine the effectiveness of this first experimental arrangements:

(i) The optimum length of intake No. 1 with a full size wheel was assessed to be approximately equal to the width of the wheel, i.e. $2\frac{1}{2}$ in.

(ii) The optimum size of the intake No. 2 was found to be about 0·15 sq. ft. ($3\frac{1}{2}$ in. $\times$ $5\frac{1}{2}$ in.) and its position to be about 1 ft. 9 in. from the centre of the grinding wheel. If placed closer to the wheel, a certain amount of fine dust escaped this intake and followed the large particles. On the other hand, by adjusting the intake to operate further away from the wheel, the spread of the primary stream made it impossible to bring the fine dust under control, although its velocity was lower.

(iii) With both intakes adjusted to optimum sizes a satisfactory control of smoke while grinding wood and of fine dust while grinding steel castings or pig iron was obtained, providing the grinding operation was carried out with little "sideways" or lateral swing of the wheel.

The sideways swing of the grinding wheel during grinding resulted in moving the suction intakes away from the primary dust stream, the effectiveness of dust control decreasing as the speed of sideways movement was increased.

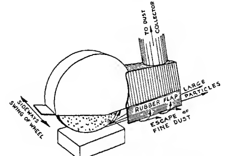


Fig. 48. Development Stage 2 showing the position of side flaps extending downwards and indicating the escape of fine dust which occurs while swinging the wheel sideways during grinding.

It was concluded, therefore, that by enclosing the dust stream at the sides, this undesirable effect might be corrected. For this purpose two rubber sheet flaps were fitted, extending downwards from the sides of the attachment, as shown in Fig. 48.

Trials were disappointing, however, in that the fine dust of the primary stream was seen to escape underneath the bottom edges of the flaps.

In a further attempt to correct the failure described above, horizontal flanges or extensions were fitted to the bottom edges of the attachment, Fig. 49. An improvement while grinding with sideways swing was noticeable at once, but control was not completely satisfactory. A certain amount of dust continued to escape, as indicated in Fig. 49.

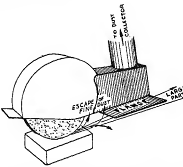


Fig. 49. Development Stage 3 showing the position of horizontal flanges and indicating the direction of escape of fine dust.

By extending the horizontal flanges towards the "front" of the wheel hood, see Fig. 50, a satisfactory improvement in the control of fine dust in the primary stream was achieved. It was further observed that this extension of horizontal flanges affected the flow of the air current produced by the fan effect of the flat faces of the exposed part of the grinding wheel. This current was directed along and underneath the flange. In effect, the fan action of this part of the wheel was utilized for directing the dust towards the exhaust intakes. It can be seen from Fig. 50 that the horizontal flange was extended also in the opposite direction beyond intake No. 2, a modification which further improved the pattern of air flow towards the intake.

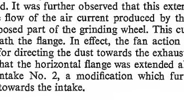


Fig. 50. Development Stage 4, showing the position of intakes and the extended flange.

(*b*) *Exhaust Rate and Velocities of the Air-Stream*

These preliminary stages of the experiments showed that a satisfactory control of the fine dust can be obtained with the exhaust rate as low as 600 cu. ft./min., providing the grinding wheel is in contact with the work at its lowest point, i.e. the direction of the primary dust stream is essentially parallel to the main axis or beam of the machine.

If, however, the point of grinding be nearer the trailing edge of the hood, i.e. grinding is done with the "front" part of the wheel, then the primary dust stream is directed downwards and away from the exhaust intakes, the influence of the exhaust on the dust stream being thereby reduced. The position of the exhaust openings cannot be lowered without interfering with the operation of the machine and, therefore, in order to extend the sphere of influence of the exhaust, it is necessary to increase the volume of the exhausted air.

On the hasis of visual observations of the dust flow, it was assessed that with an exhaust rate of 900 cu. ft./min. a satisfactory degree of control of the fine dust was obtained when the primary stream was directed downwards at angles of up to 45° in relation to the main axis of the machine.

As shown in Fig. 50, the gap at the trailing end of the hood was sealed hy means of a slide that could be adjusted as the wheel became worn. However, when the exhaust volume was increased to 900 cu. ft./min., it was noticed that, if this gap was left open, there was a current of air flowing into the hood through this gap. This suggested that the adjustable slide, which is not a convenient or practical fitting, might be omitted. This possibility was studied more closely, by the observation of dust movement and the measurement of air velocities. With no exhaust in operation the fan action of the rotating wheel produced a current of air which left the hood with velocities of 4,100 cu. ft./min. close to the wheel periphery, 2,700 ft./min. at the edge of the hood and 3,200 ft./min. at the centre of the gap. With the exhaust in operation air velocities were measured not only in the opening, but also inside the hood. These have shown that at an exhaust rate of 900 cu. ft./min. the slip-stream of the wheel is completely overcome by the exhaust air over the whole area of the opening, Fig. 51. This reversal of the air flow in the opening at the trailing edge of the hood at the exhaust rate of 900 cu. ft./min. produces a current of air flowing into the hood with a velocity of 900 ft./min. close to the wheel periphery and 1,700ft./min. in the centre of the opening; and prevents the secondary dust stream generated by the grinding of steel castings from emerging from the hood.

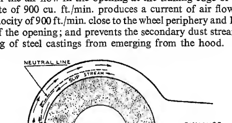


Fig. 51. Diagram of air flow at the opening and inside the hood at the trailing end of the wheel. Exhaust 900 cu. ft./min. Peripheral velocity 9,000 ft./min.

(*c*) *Effect of Wheel Size*

When a worn down wheel was fitted (10 in. dia.—peripheral velocity 5,625 ft./min.) observations when grinding wood and pig iron revealed a satisfactory control. Fig. 52 shows the dust stream generated by grinding pig iron so that the dust stream was directed at an angle of about 45° to the beam of the machine. With an exhaust volume of 900 cu. ft./min. the control of this intense dust stream is effective.

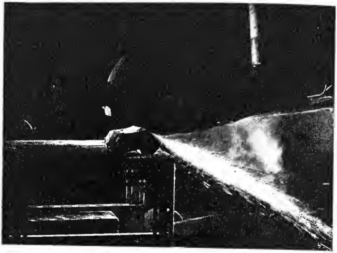


Fig. 52. Control of dust when grinding pig-iron with a worn-down wheel, exhaust 900 cu. ft./min. Although the grinding position is such that the sparks are projected at a 45° angle, the fine dust is brought under control.

(*d*) *Influence of Exhaust on Atmospheric Dust in the Vicinity of the Trailing Edge*

It has frequently been observed that the vibration of the work-piece or casting during grinding causes dust on the work-rest or floor to become airborne, in which case some of it rises towards the operator's breathing zone. However, when employing the exhaust rate of 900 cu. ft./min., it was observed that this airborne dust was sucked into the trailing end of the hood.

A series of air velocity readings was therefore taken outside the hood at various distances along the lines shown in Fig. 53. On the basis of these results, the velocity contours of the exhaust air flowing into the trailing end of the hood were drawn. From these it will be seen that air moves towards the hood opening at a velocity of 75 ft./min. at a distance of approximately 5–8 in. from the opening.

In addition, therefore, to providing a satisfactory degree of control of the primary and secondary dust streams generated by grinding, the higher exhaust rate of 900 cu. ft./min. now recommended can be said to have the auxiliary function of affording some additional protection to the operator by preventing

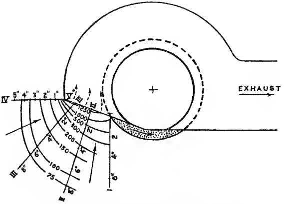


Fig. 53. Velocity contours of exhaust air flowing towards the opening at the trailing end of hood. Wheel 10 in. dia. Peripheral velocity 5,625 ft./min.

some of the loose dust around the casting being ground from entering his breathing zone.

(e) *Air Current Generated by the Driving Belt*

The lower line of the driving belt, which runs towards the back of the machine, generates a current of air flowing in the same direction. It has been observed that at a distance of about 9 in. from the exhaust intakes this current is strong enough to overcome the air flow towards the exhaust system and carries the dust clouds towards the back of the machine. Therefore, the belt should be encased at least on the side facing the beam of the machine.

(f) *Recommendations*

The B.S.C.R.A. integral exhaust system has been shown to be effective when applied to a standard machine with 16 in. dia. grinding wheel operating at a peripheral velocity of 9,000 ft./min., to which the following modifications were introduced, Fig. 54:

(i) closing the gaps between the side plates of the hood and the sides of the grinding wheel;

(ii) intake No. 1, nearest wheel, should be 2 in. long (with 16 in. dia. wheel fitted);

(iii) intake No. 2 should be 3½ in. long by 5½ in. wide and positioned so that its centre line is 1 ft. 9 in. from the centre of the grinding wheel;

(iv) the flange should extend from the axis of grinding wheel to a distance 18 in. behind intake No. 2 and should be of a total width of 18 in., so that it projects not less than approximately 6 in. on either side of the side plates of the hood;

(v) the driving belt should be encased.

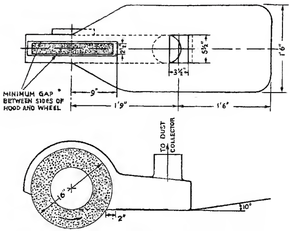


Fig. 54. Design of the exhaust hood, showing the sizes and positions of the intakes and the flange.

For an effective dust control an exhaust rate 900 cu. ft./min. at 3¾ in. w.g. static pressure is required.

5. *The B.S.C.R.A. Combined Booth and Integral Exhaust System*

(*a*) *Experimental Considerations*

The integral exhaust system on the swing frame grinder described above, although effective in the control of fine dust generated during grinding of steel castings, has some features which might be inconvenient under some conditions of operating the machine. These limitations are due mainly to the application of a flexible exhaust pipe and flanges extending at the rear of the hood, which may restrict the manœuvrability of the machine.

It is obvious that the booth exhaust system is free from these particular restrictions, but observations have shown that, although the control of the primary dust stream does not present any difficulties, the secondary dust stream cannot, under various conditions of grinding, be controlled successfully even when very high exhaust volumes (6,000 cu. ft./min.) are employed.

(*b*) *Experimental Equipment and Procedure*

Preliminary work was carried out on a combined exhaust system, the principle of which is shown in Fig. 55. The primary dust stream was controlled by the flow of air into a booth through which 2,000 cu. ft./min. was exhausted. The velocity of the exhaust air was approximately 75 ft./min. in the booth opening. To control the secondary dust stream a fan of 100 cu. ft./min. capacity, driven by a ½ h.p. motor, was fitted on top of the swing frame grinder (see Fig. 56). The suction side of this fan was connected with the grinding wheel cowling through the hollow beam of the machine (if a machine has a solid beam, a pipe connecting the fan with the wheel cowling can be fitted easily): The wheel

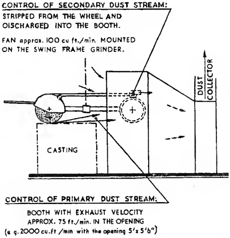


Fig. 55. The B.S.C.R.A. combined booth and integral exhaust system.

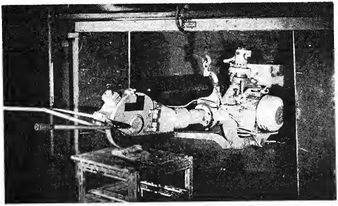


Fig. 56. View of the experimental arrangement of the combined exhaust system. Note a small fan mounted over the electric motor.

cowling was modified according to the B.S.C.R.A. integral exhaust system, excluding the fitting of the flange. The outlet of this fan was directed towards the booth opening so that the fine dust stripped from the grinding wheel was discharged into the booth. No flexible pipe is required and no restrictions are imposed on the movements of the machine.

(c) *Dust Control Observations*

Observations at the Dust Research Station have shown that a combined booth and integral exhaust system provides a satisfactory control of dust when grinding with either a full size wheel (16 in. dia.) or a worn-down wheel. Even when the grinding wheel was several feet in front of the booth opening, which might occur when grinding large castings, the effectiveness of this exhaust system was maintained, providing the primary dust stream was directed into the booth opening.

It would appear that the combined exhaust system not only secures a high degree of dust control, but is also likely to show to advantage in capital and operating cost as compared with the plain booth exhaust.

Conclusion

Both the E.S.C. and B.S.C.R.A. integral exhaust systems, as well as the combined booth and integral exhaust system, provide an effective means of dust control on swing frame grinding machines, and the decision whether the integral system or the combined booth and integral system would be most suitable will depend on the particular type of machine and its operating conditions.

The integral exhaust systems are protected by British Patents and manufacturers have been licenced to produce machines, which are now commercially available, and incorporate these systems of dust control.

The combined integral and booth exhaust system is protected by British Patent Application No. 774,147.

Acknowledgements

The Association acknowledges a general financial contribution provided by the British Steel Founders' Association towards the cost of these investigations.

The Association also has pleasure in recording its thanks to several Members of the Association and manufacturers of foundry equipment for assistance in the experimental work.

APPENDIX XV

Low Volume High Velocity Dust Control for a Pneumatic Chisel

1. Pneumatic chisels have heen commonly used in the past without any kind of dust control, although if the work is small enough to he dealt with on a bench, the bench itself may be fitted with local exhaust ventilation[12]. Recent development work, however, has resulted in an original approach to the problem which has provided local exhaust ventilation for the portable tools themselves so that some form of dust control unit is now availahle for work which is either too heavy or too hig to he handled on henches.

2. The research work was done hy two memhers of an industrial firm, Mr. A. T. Holman and Mr. E. B. James, together with a memher of our Committee, Mr. W. B. Lawrie, and it resulted in the first integral local exhaust ventilating system, to he fitted to a pneumatic chisel[35]. It was evident from the outset that the system should form an integral part of the tool and that it would have to be light and neat in construction in order to preserve the flexihility of the operation which is a first essential of pneumatic chisels. It had already heen shown that the fine dust from a pneumatic chisel flows up the chisel shank and follows the line of the operator's arm to rise to his face[12]. This effect can he seen from Fig. 1, which is reproduced from the original film negative from which the effect was discovered. Early experimental work in mining practice had shown that dust could he controlled in the process of rock drilling hy

Fig. 57. Dust control by external duct held over chisel point.

secondary forcing jet to induce a lower velocity air stream round the edge of the cone. The secondary induced stream collects larger quantities of heavier dust which would otherwise escape from the system.

8. Once again the system was examined by means of the illumination technique and Figs. 64 and 65 are reproduced from the original film negative[39]. Fig. 64 shows the conditions when stripping a heavy steel casting without exhaust ventilation. Fig. 65 is a corresponding photograph taken with the ventilating system in use and the extension duct fitted over the chisel sleeve. Heavy particles and chips can be seen flying from the chisel point, but the main dust cloud within the respirable size range appears to be under control.

Fig. 60. Pneumatic chisel fitted with rubber sleeve.

Fig. 61. Pneumatic chisel cutting flash from a grey iron casting which had been shot blasted. No exhaust ventilation in use.

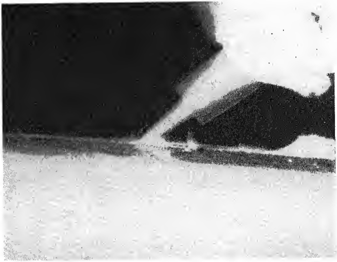


Fig. 62. Rubber sleeve fitted to chisel and exhaust system operating. All other conditions as in Fig. 61. Note dust flowing into sleeve ducts above and below chisel cutting edge.

Fig. 63. Pneumatic chisel showing conical extension duct fitted over rubber sleeve. Polythene hose connected to sleeve.

Fig. 64. Stripping heavy steel casting with pneumatic chisel. No exhaust ventilation in use.

Fig. 65. Stripping heavy steel casting with pneumatic chisel with sleeve and conical extension duct. Exhaust ventilation system working. Heavy particles flying from chisel. (Cp. Fig. 64.)

APPENDIX XVI

Low Volume High Velocity Dust Control for a Portable Grinder

1. Very heavy dust concentrations may be developed by the use of portable grinders and much of the dust so produced will be within the respirable size range. It may be possible to put small work on to a bench which can be fitted with local exhaust ventilation, but much of the work which is ground by portable machines is either too big or too heavy to be treated in this fashion. In consequence, portable grinders have often been used without dust control and the effects of this method of working appear in the dust concentration figures to which reference has already been made[9]. The Joint Standing Committee on Conditions in Iron Foundries decided that this matter should be investigated and in consequence two members of an industrial firm, Mr. A. T. Holman and Mr. E. B. James, and a member of our Committee, Mr. W. B. Lawrie, together began research and development work on the problem in 1953. Their object was to develop a dust control system which would provide protection from the dust and, at the same time, form an integral part of the portable machine. It was clear that the proposed dust control system would have to be inconspicuous and very light in weight so that the portable machine would retain its flexibility of operation and, as this was the first time that any attempt had been made to exhaust dust through the guard of a hand grinder, the investigators had no previous experience to guide them. They began, therefore, by examining the aerodynamics of the machine by means of the dust observation technique.

2. The preliminary work was done on a Series 40 Holman Grinder fitted with a 6 in. diameter wheel with a free running speed of 6,000 revolutions per minute and a peripheral speed of 9,000 feet per minute. A 5 in. diameter wheel was also used during the tests in order to estimate the effect of wheel wear[35]. The prototype that was developed is shown in Fig. 66. The wheel guard was fitted with a peripheral duct which conformed to its curved edge and three ports opened on the inside curved surface of this duct which was also connected to a $\frac{5}{8}$ in. diameter flexible pipe. In the experimental work the exhaust was obtained by a compressed air "Eductor". Fig. 3 shows the condition that resulted from using a portable grinder in laboratory conditions without exhaust ventilation. Fig. 67 was taken from the cinematograph film negative that was used during the development of the new low volume high velocity exhaust system. It shows the fine dust under good control even in the worst conditions with the leading edge of the hood lifted as far above the work as possible. The wheel is rotating in an anti-clockwise direction and is grinding grey iron. Heavy particles can be seen falling to the floor but the main dust cloud is under good control. The dust which has passed the leading edge of the guard on the right is being brought back by the induced air stream.

3. Preliminary dust counts were also taken in laboratory conditions[37, 38]. These confirmed the observations and photographs and indicated that the new system gave a high level of dust control when working in laboratory conditions.

4. The hood on which the system was developed covered a large proportion of the wheel face and, in consequence, may be impracticable on certain work. The original work had, however, provided a dust control system which was

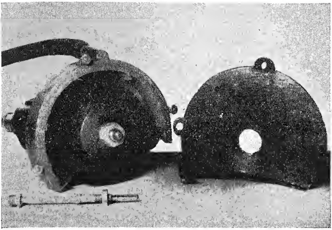


Fig. 66. Wheel hood with front plate removed.

Fig. 67. Dust control when grinding grey iron with exhaust system operating at 5 in. of mercury. Heavy particles falling. Right-hand edge of dust cloud under control by the induced air.

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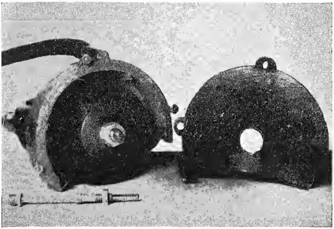

Fig. 66. Wheel hood with front plate removed.

Fig. 67. Dust control when grinding grey iron with exhaust system operating at 5 in. of mercury. Heavy particles falling. Right-hand edge of dust cloud under control by the induced air.

useful enough in some cases. It had shown that the dust could be controlled from portable grinders and it had established a new principle in local exhaust ventilation. In consequence, another group of workers consisting of Mr. A. T. Holman and Mr. F. F. L. Morgan, of an industrial firm, and Mr. W. B. Lawrie, from our Committee, undertook to investigate the problem of applying the new system to the various circumstances in which portable grinders might be used. They first cut back the hood until it covered little more than half of the wheel and, at the same time, they succeeded in retaining control of the dust. The next step was to remove the hood when it was discovered that the dust could be controlled through a curved peripheral duct which extended over about one-third of the wheel circumference[42]. Once again the dust was kept under control. Finally, an extractor head was developed so that the maximum amount of wheel face could be exposed for grinding[39]. Fig. 68 shows the extractor head in operation. The head is provided with a port on its inner surface to which has been added an aerofoil vane so that the dust is stripped from the wheel face. Heavier particles, dust and sparks which flow along the line of the work tangentially to the wheel face are collected through a second port in the lower surface of the extractor head. A roller device has been fitted to the front of the head so that it will run more easily over the work and as the tangential stream of dust and sparks strikes this roller it decelerates before being collected by the port immediately above it. The head can be adjusted quite simply to all wheel diameters from 8 in. down to $2\frac{1}{2}$ in., so that it can be kept in close proximity to the wheel as it wears. The prototype was constructed for a wheel 1 in. wide and it extracted 40 cubic feet of free air per minute at a vacuum head of 5 in. of mercury through a $\frac{3}{4}$ in. plastic hose.

Fig. 68. Grinding grey iron with extractor head fitted and operating. (Cp. Fig. 69.)

5. The machine was developed by means of the observation and photographic technique and Figs. 68 and 69 indicate the measure of dust control that was achieved. Dust counts taken by means of the thermal precipitator, the Konimeter and the Owens Jet Counter confirmed the visual observations and the photographs[39].

6. The extractor head which was developed collects some sparks as well as dust and when certain types of steel are ground the sparks may either obstruct the inlet ports or, if they pass down the polythene hose, may soften the plastic wall so that the hose collapses and obstructs the air flow. A spark trap has been

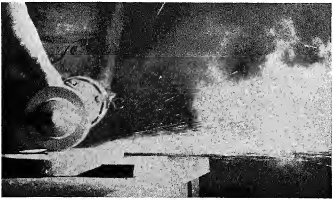

Fig. 69. Grinding without local exhaust ventilation.

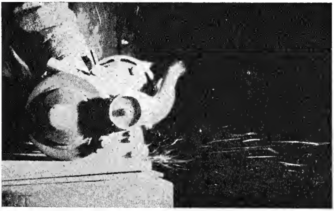

Fig. 70. Grinding steel with extractor head and spark gap fitted and operating.

designed to overcome this difficulty[40]. A rotor is placed inside a cylinder mounted on the extractor head so that it revolves in the air stream. The sparks impinge on this rotor and are cooled before being carried down the hose. The extractor head is still easily adjustable for wheel sizes from 8 in. down to $2\frac{1}{2}$ in. diameter and extracts 40 cubic feet of free air per minute through a $\frac{3}{4}$ in. plastic hose at a vacuum head of 5 in. of mercury. The spark trap which does not impair the dust control system weighs only $3\frac{1}{2}$ ounces. Figs. 69 and 70 indicate the measure of dust control that was achieved.

APPENDIX XVII

Low Volume High Velocity Dust Control for a Portable Surface Grinder

1. Large surfaces are often ground by means of a portable surface or disc grinder in which the side of the wheel is used for grinding and not the edge. These machines frequently produce very dense dust clouds, the control of which has been a matter of great difficulty. Various kinds of hoods and booths have been tried, but because the articles being worked are often large and the surfaces to be ground are awkwardly placed it has proved impossible always to ensure that the operator will never work between the point of dust generation and the exhaust hood. As a result, even when the hoods have been used, the dust has often been extracted through the operator's breathing zone. In these conditions a hood may serve some purpose in extracting dust which would otherwise contaminate the general atmosphere of a building, but it has little value to an operator who must breathe the dust-laden air as it passes his head.

2. The problem was put by a foundryman to a member of the Joint Standing Committee on Conditions in Iron Foundries and as a result research was begun

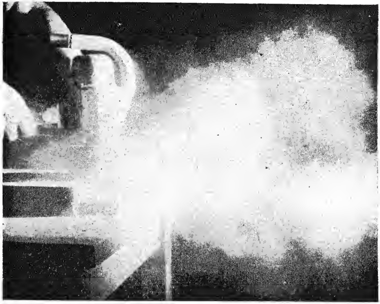

Fig. 71. Surface grinder without exhaust ventilation.

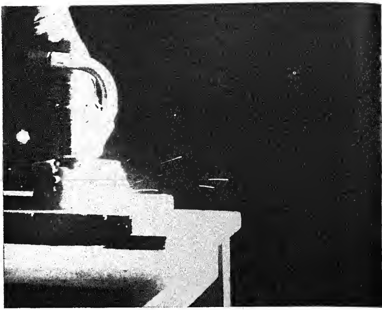

Fig. 72. Surface grinder with local exhaust ventilation fitted and operating.

on it by Mr. A. T. Holman and Mr. E. B. James of an industrial organisation, together with Mr. W. B. Lawrie of our Committee[38]. The illumination technique was used to explore the dust movement generated by the wheel, to develop the dust control system and to estimate the efficiency of the completed unit and the low volume high velocity system was again applied. In the experimental work the ventilating air was once more induced by an air ejector but a rotary exhauster or a fan could be used equally well.

3. The air was extracted from the first successful machine through ports placed all round the inner edge of a ring which completely surrounded the wheel[38]. Later work[39] showed that this ring did not need to encircle the wheel and that the dust could still be controlled if a section of the duct were cut away as shown in Fig. 72. This modification allows the operator to see his work and also facilitates the use of the wheel close up to projections and in corners.

The extraction of about 33 cubic feet of free air per minute at a vacuum of five inches of mercury was found to give good dust control. Figs. 71 and 72 indicate the measure of success when the machine was being used to grind a grey iron casting and dust counts taken in laboratory conditions confirmed these observations.

APPENDIX XVIII

Low Volume High Velocity Dust Control for a Cone Grinder

1. The successful development of the low volume high velocity local exhaust ventilating system led the Joint Standing Committee on Conditions in Iron Foundries to consider the problem of dust control on cone grinders. Cone wheels are normally used in internal cavities or in external recesses so that hoods cannot be fitted to them. It seemed possible, however, that the new integral system might be fitted and so Mr. A. T. Holman and Mr. J. L. Burgess of an industrial firm and Mr. W. B. Lawrie from our Committee began a further research and development project on these machines.

2. It was found that the dust from a three-inch diameter wheel could be controlled by a new type of head which was fitted just behind the wheel itself[41, 60]. The head extracted 40 cubic feet of free air per minute through a $\frac{3}{4}$ in. plastic hose at a vacuum head of five inches of mercury, and Figs. 73 and 74 indicate the measure of dust control that was achieved when using this extractor head on a grey iron casting.

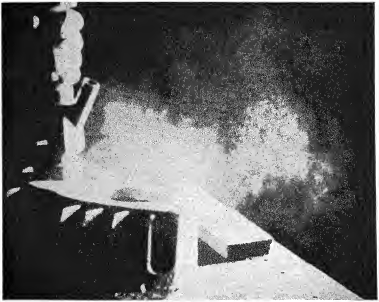

Fig. 73. Cone grinder without local exhaust ventilation.

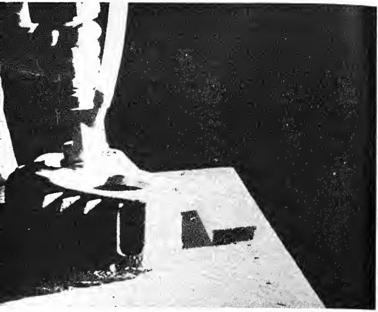

Fig. 74. Cone grinder working with local exhaust ventilating system fitted and operating.

3. The head was also adapted for use on a 1 in. diameter wheel when about 15 cubic feet of free air per minute was extracted through a $\frac{3}{8}$ in. hose at a vacuum of five inches of mercury. Dust control of a high standard can now be fitted to all cone wheels and also to the very small flexible shaft-driven mounted points.

APPENDIX XIX

Low Volume High Velocity Dust Control for Swing Frame Grinders

1. The development of the low volume high velocity system for portable tools led to a request that it be adapted on swing frame grinders. The system would, of course, use less air than other methods and this might offer some advantage in a foundry, but what was perhaps more important was that the small diameter ducting would allow full flexibility to the machine. The necessary development work was undertaken by Mr. A. T. Holman, Mr. E. B. James, Mr. F. F. L. Morgan and Mr. J. L. Burgess of an industrial organisation, together with Mr. W. B. Lawrie of our Committee.

2. In the first instance the wheel guard was fitted with a peripheral duct with a series of ports on its inner surface. It was shown that the dust could be controlled by the extraction of about 250 cubic feet of free air per minute at a vacuum head of three inches of mercury through a 3 in. diameter hose[38]. As a second stage in the work the system was adapted for use on a transverse swing frame grinder when the peripheral duct was not used because the investigators decided to adapt the extractor head which had by this time been developed for the edge running portable grinder. The head, which was twice the size of the one used on the portable grinder, extracted 150 cubic feet of free air per minute at a vacuum of five inches of mercury and it was connected to the extraction plant by a light-weight hose of 1½ in. diameter[39]. Finally, a new type of head was developed which gives good dust control when extracting about 250 cubic feet of free air per minute at a vacuum of five inches of mercury through a 2 in. hose.[41, 60]

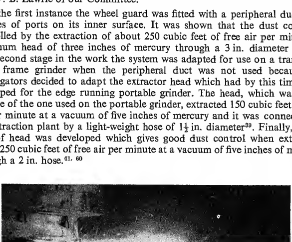

Fig. 75. Swing frame grinder working on grey iron without exhaust ventilation.

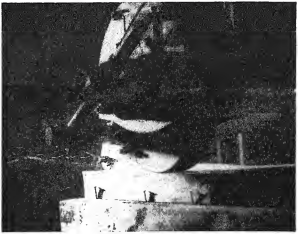

Fig. 76. Swing frame grinder working on grey iron with extractor head fitted and operating.

3. Once again the development work was based on observations and photographs and Figs. 75 and 76 indicate the standard of dust control that has been achieved on swing frame grinders. The visual evidence obtained from the film itself was confirmed by dust counts which also showed a high standard of dust control in the laboratory conditions under which the machines were tested.

Experiments with Air-Supplied Respirators

A Communication from the British Steel Castings Research Association

Although considerable improvements have been made in the methods of suppression of dust at the source in the fettling and cleaning of castings, the efficiency of these various methods is far from being 100% in all cases. The necessity remains, therefore, for providing personal protection for the operator in the form of respirators or masks and for improving the comfort to the wearers of these devices.

A mask fed with clean air provides an atmosphere which is independent of the working environment, but the air supply pipe restricts the wearer's movements and the constant high rate of air-supply, which is necessary to provide an adequate supply for the peaks of inhalation at periods of heavy work, can be a cause of considerable discomfort.

Respirators are provided with air-filters, which make breathing more difficult as they become clogged with dust extracted from the inhaled air. The complaint is often made, however, that they are not comfortable to wear in a hot environment and, in any case, they do not afford complete protection unless a perfect fit to the wearer's face is ensured.

Compromise solutions, in which clean air is fed into a filter respirator, are being developed by two Member Firms of the B.S.C.R.A. The main difference between the two developments is in the point of introducing the clean air in relation to the filter pad. In one case the air is fed in front of the filter and in the other case behind the filter.

The Association's own participation in developments in this field has been confined to improving the design and efficiency of a prototype face mask by Mr. R. J. Richardson. This work resulted in the design of a combined mask and eye-shield made of transparent "Perspex", as illustrated in Fig. 77. In this appliance fresh air is supplied continuously to the cavity of the mask through holes (1 mm. dia.) in a horizontal "Perspex" tube, which is fitted in the mask at the level of the mouth. Exhaled air and the excess of supplied air escape downwards to prevent the ingress of dust-laden air from the surrounding atmosphere.

In order to provide air at a rate sufficient to match the speed of inhalation, it must be supplied at at least three times the rate corresponding to the total air inhaled per minute (the minute volume). Tests on this mask carried out by the Safety-in-Mines Research Establishment have shown that at a minute volume of 1·5 cu. ft., which corresponds to hard work, a supply rate of the order of 6 cu. ft./min. would be required to provide adequate protection. This rate is too high for comfort and, since the mask does not provide adequate protection at lower rates of air supply, it has not been approved by the Factory Department. The mask also suffers from the disadvantage that its fitting to the face is fairly critical. If the gap between the bottom of the mask and the chin of the operator is too great, the efficiency is markedly reduced. For these reasons

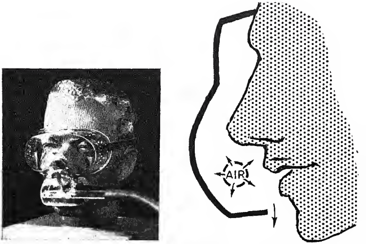

Fig. 77. Photograph and diagram of the B.S.C.R.A. air feed mask.

this mask cannot be recommended for use in foundries in its present stage of development.

MICROFILTER WITH AIR FEED

The two Member Firms of the Association, who have experimented with the supply of clean air into a standard respirator, have agreed to the Association making this information available. Both firms have utilized a Siebe-Gorman Microfilter, which is the most common type of respirator used in steel foundries, but the point at which the clean air introduced into the mask was different in the two cases. In one case the clean air was supplied into the mask cavity at the back of the filter and in the other case it was supplied in front of the filter.

Developments at Osborn Foundry and Engineering Co., Ltd.

It is of interest to note that in this case the primary concern of the management was to improve conditions for an operator using an iron-powder cutting torch. The volume of fumes generated during this operation is considerable and of very fine particle size, so that even with a high efficiency respirator a small amount of fume passes through the filter and is noticeable to the operator. Another important factor which contributes substantially to the discomfort is that the fumes are hot and, under some conditions of operating the torch, the air reaching the operator's breathing zone is uncomfortably warm. The application of a fresh air-supply is ideally suited to this case.

A Microfilter respirator was used, Fig. 78, and in order to supply the fresh air into the cavity of the respirator a "Perspex" tube (approximately $\frac{3}{8}$ in. dia.) was fitted into the wall. The section of the tube inserted inside the respirator was provided with perforations to diffuse the air in a similar manner as in the B.S.C.R.A. air-feed mask. To avoid any direct impingement of air on the face

the tube was not perforated on the side facing the wearer's mouth and nostrils. A rubber hose, which connected the respirator with the air-supply line, was fastened to an arm-strap to eliminate a pulling action on the mask.

From the above description and the diagram in Fig. 78 the purpose in introducing the fresh air at the back of the filter can be seen. Clean air is supplied only at a rate corresponding to normal inhalation and the extra air required during periods of heavy work and heavy breathing can be freely drawn by the operator THROUGH THE FILTER from the surrounding atmosphere. The same will apply if, for some reason, the rate of air-supply falls below the nominal figure. This provision for the extra air, if required, to be filtered is important in view of what has been said previously regarding the increased demand for air at the peak of inhalation. Fresh air might be supplied to the respirator at a rate well below the maximum required for short periods of peak inhalation, which might be desirable for the comfort of the wearer in some conditions such as cold weather, but he will be protected from breathing the dusty shop atmosphere providing, however, that the respirator is well fitted on to his face so that the extra air will pass through the filter and will not leak through gaps between his face and the respirator.

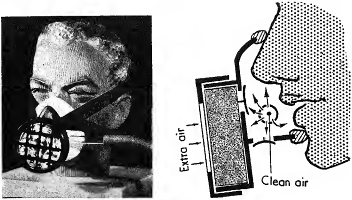

Fig. 78. Photograph and diagram of a MICROFILTER with air feed developed by OSBORN FOUNDRY & ENGINEERING CO., LTD.

A proper fit of the respirator to the wearer's face is therefore as important in this development, in particular at low rates of air-supply, as it is when the respirator is used in the normal way.

Preliminary tests were carried out with several operators, who were allowed to adjust the rate of flow to suit their own comfort, and the air flow was measured. The figure obtained varied from approximately 1 to 2½ cu. ft./min., which would indicate that it might be advisable to provide each wearer with some means for adjusting his own air supply.

At the present stage of development, if the wearer disconnects the air-supply pipe from his respirator, the shop air will short-circuit the filter pad through the "Perspex" tube. This point has been considered and, if the necessity arises,

it should be possible to fit in the inlet to the "Perspex" tube a suitable valve, which will ensure that when the fresh air-supply is cut off the shop air will pass through the filter.

The air supply to the respirator was taken from the compressed air lines, passed through a filter and a reducing valve, in a similar way as the air feed to helmets of operators working in shot blast cabinets.*

There is a considerably lower usage of filter pads, but the cost of supplying air should be set against the saving in filters. If a respirator is used in the normal way, i.e. without the air feed, it is necessary in some cases to change the filter twice in a shift, when worn by operators engaged in powder cutting. During a period of several months of using the respirator with the air feed, it was sufficient to provide a new filter pad once a week only.

Development at Jackson, Elphick and Co., Ltd.

Air-fed respirators have been used by this firm for some years in the bath enamelling shop, where they have proved very successful. Now their application is being extended to the steel castings fettling shop.

The clean air is fed into a Microfilter respirator through a "Perspex" tube ($\frac{3}{4}$ in. dia.) mounted on a plate which fits in front of the filter pad, Fig. 79. A flexible rubber hose connects the respirator with the air-supply line and to avoid a "pull" on the respirator, the rubber hose is fastened to a leather belt worn by the operator.

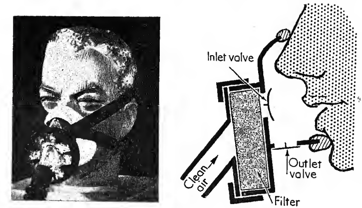

Fig. 79. Photograph and diagram of a MICROFILTER with air feed developed by JACKSON, ELPHICK & CO., LTD.

As can be seen from the diagram in Fig. 79 and the above description there are two characteristic features in this development. The first one is that the total volume of air required by the wearer must be delivered through the

* Some information on this subject is contained in a Code of Practice formulated by I.C.I. Ltd.: Section 17—Compressed Air Service for Breathing Apparatus. This is NOT a statutory regulation or part thereof.

feeding pipe as there is no other access for the air, providing of course that the face-piece fits correctly. To ensure, therefore, a sufficient volume of air for periods of heavy work and peaks of inhalation, the rate of air-supply is kept continuously at the maximum possible level of demand. With the excess supply of air, a good fit of the mask to the operator's face is not particularly important, as any slight leak is taken care of by an outflow of air. In order to ensure the comfort of the worker at these high rates of air-supply, it is essential that the air is properly conditioned in temperature and humidity, especially during cold weather. This was achieved by passing the filtered air over mercury arc rectifiers so that a certain degree of sterilization takes place in addition to heating. In the summer time, or in hot weather, this circuit is by-passed so that the cold air supplied from outside has a very beneficial cooling effect on the wearer of the mask.

The other main feature in the development is that air which is delivered by a constant speed centrifugal fan at 5 in. W.G. pressure is supplied in front of the filter. This acts as a diffuser in addition to its filtering action. Even if the air supplying pipe is disconnected from the respirator, the wearer will be protected because he will draw the air from the surrounding environment through the filtering pad of the Microfilter. There is no need to equip the respirator with an additional valve as might be necessary in the development shown in Fig. 78.

It was found that with this system a filter pad lasts about a week and a pad is discarded when discoloration penetrates about one-third of its normal thickness.

The air is distributed in the shop by a 2 in. dia. overhead duct, from which branches of 1 in. dia. pipes are placed at various positions so that the operators can plug in their connecting pipes by means of a simple bayonet fitting.

Conclusion

The two developments in supplying fresh air to the face-pieces of Microfilter respirators are experimental in nature but deserve close attention, since they both offer a means of improving comfort in wearing respirators of this type.

Acknowledgement

The Association's thanks are due to Messrs. Jackson, Elphick and Co. Ltd. and Mr. James Jackson, and Messrs. Osborn Foundry and Engineering Co. Ltd. and Mr. W. Herring, for making available the information on their developments.

Dust Collection in Foundries

A Communication from the British Steel Castings Research Association

There are three main reasons for separating and collecting from the entraining gas the dust and fumes produced in industrial processes. If gas is to be used as a fuel, as for example blast furnace gas for heating stoves and for gas engines, it is necessary to extract the dust from gas before the latter can be used. In some processes it might be an economical advantage to separate and collect the dust because of its intrinsic market value, even though the gas itself is useless. Finally, dust may be collected before the gas is discharged into the atmosphere in order to avoid or to reduce the contamination of the atmosphere and the deposition of dust in the surrounding area.

The problem of dust collection in the steelfounding industry belongs to the last group, in which neither the dust collected nor the cleaned gas (air) have any intrinsic value. The possibility of recirculating the cleaned air into the shop, in order to reduce the heat losses associated with large volumes of exhausted air, is a controversial subject but, in general, this practice is not recommended in particular when dealing with toxic dust. In connection with the collection of foundry dusts, it was suggested that, because of the value of some alloying elements, in particular of nickel, it might be worth considering the recovery of grinding dust from heat resisting and stainless steel castings.

Types of Collectors for Foundry Dusts

It would be beyond the scope of this note to describe the various types of dust collectors available, but it is of interest to note that a review of this subject has been made by C. J. Stairmand[51]. Tables I, II and III are taken from Stairmand's paper. Table I gives the overall collection efficiency of various types of dust collector, which were tested by means of a standard dust, the grading of which is given in Table II. Table III gives details of the approximate costs of the various dedusting systems compared on the basis of treating 60,000 cu. ft./min. at a temperature of 68°F.

An attempt is made to outline the types of collectors that are being used for dust and fumes from various operations in a steel foundry.

Sand Preparation Plant

The amount of dust generated during the different stages of sand preparation will depend in the first instance on the moisture content in the sand. Only when it is in a dry state will sand become airborne easily and produce dust clouds during handling. If it were possible to keep the moisture content throughout the mass of the sand above one-half of the nominal working range of moisture, no dust problem would be associated with the handling of sand, even in a mechanical plant.

The equipment requiring local exhaust ventilation in a sand handling and preparation system is as follows: rotary screens, bucket elevators, belt conveyors, mixers and transfer points. It is usual practice to consider the

collection of dust from knock-out stations separately, because of the different characteristics of the dust and fumes generated there.

The range of particle size in the dust produced in sand preparation will vary from very fine (under 2 μ) to medium size (say up to 30 μ). The types of dust collectors used in this case are the cyclones, or wet collectors. Fabric filters might be troublesome, due to condensation and subsequent clogging of the fabric. It can be seen from Table I that in the case of a tubular cyclone or a spray deduster their overall efficiency (93%) is much higher than can be expected from a medium-efficiency cyclone (65%).

TABLE I

Overall Collection Efficiency on Standard Test Dust
(After Stairmand[44])

Apparatus	Overall Efficiency %	Efficiency, %		
		5 microns	2 microns	1 micron
Medium-efficiency cyclone	65·3	27	14	8
High-efficiency cyclone	84·2	73	46	27
Low pressure-drop cellular cyclone	74·2	42	21	13
Tubular cyclone	93·8	89	77	40
Irrigated cyclone	91·0	87	60	42
Electrostatic precipitator	94·1	92	85	70
Irrigated electrostatic precipitator	99·0	98	97	92
Fabric filter	99·9	>99·9	99·9	99
Spray tower	96·3	94	87	55
Wet impingement scrubber	97·9	97	92	80
Self-induced spray deduster	93·5	93	75	40
Disintegrator	98·5	98	95	91
Venturi scrubber	99·7	99·6	99	97

TABLE II

Grading of Standard Test Dust
(After Stairmand[44])

Size of Grade microns	Percentage by Weight in Grade	Percentage by Weight Smaller than Top Size of Grade
104–150	3	100
75–104	7	97
60–75	10	90
40–60	15	80
30–40	10	65
20–30	10	55
15–20	7	45
10–15	8	38
7½–10	4	30
[illegible]–7½	6	26
[illegible]–5	8	20
<2½	12	12

TABLE III

Approximate costs of Various Dedusting Systems Treating 60,000 cu. ft/min. of Dust Gases at 68°F. (After Stairmand[14])

The cost figures given in this table are based on 1955 values

Equipment	Capital Cost, £		Total Running Cost	Capital Charges	Total Cost including Capital Charges	
	Total	per cu.ft./min. capacity	£/annum	£/annum	£/annum	d./1,000 cu. ft.
Medium-efficiency cyclones	3,300	0·05	1,750	330	2,080	0·017
High-efficiency cyclones	6,300	0·10	2,320	630	2,950	0·025
Tubular cyclones	6,900	0·11	2,040	690	2,730	0·023
Irrigated cyclones	7,800	0·13	2,840	780	3,620	0·029
Low pressure-drop cellular cyclones	5,600	0·09	715	560	1,275	0·011
Electrostatic precipitators	30,700	0·51	870	3,070	3,940	0·033
Irrigated electrostatic precipitators	52,800	0·88	1,960	5,280	7,240	0·060
Frame-type fabric filter	17,600	0·29	5,060	1,760	6,820	0·057
Reverse-jet fabric filter	17,000	0·28	6,690	1,700	8,390	0·070
Spray tower	18,300	0·30	5,975	1,830	7,805	0·065
Wet impingement scrubber	10,300	0·17	3,750	1,030	4,780	0·040
Self-induced spray deduster	8,700	0·15	3,130	870	4,000	0·033
Venturi scrubber	15,000	0·25	12,080	1,500	13,580	0·11
Disintegrator	23,800	0·40	23,750	2,380	26,130	0·22

Knock-out

The particle size range in the dust extracted at the knock-out station will depend on the type of the local exhaust system applied. With a down-draught system and an enclosed hood larger particles, and a much higher ratio of them, can be expected than in dust extracted by a side-draught system. In the latter case mainly fine dust (under 5 μ) and fumes will be drawn into the hood, therefore only high-efficiency collectors should be considered for this duty. Fabric filters, although very efficient in this range of particle sizes, can give trouble due to condensation. It appears from Table I that only the wet electrostatic precipitator or Venturi scrubber will approach 100% efficiency for particles of 1 μ size, but it is evident from Table III that the first type is high in capital cost and the second type of collector is expensive to run, and they are probably not necessary in this application. Self-induced spray dedusters are often installed for knock-out dust and it can be seen in Table I that the efficiency of such a collector is 93% for 5 μ particles, 75% for 2 μ particles and 40% for 1 μ particles. Such a collection efficiency is probably adequate if the discharge from the collector is emitted to the outside atmosphere at a sufficient height to ensure adequate dispersion. Stairmand has pointed out that small particles fall extremely slowly and are not likely to reach ground level until well dispersed. They should not, therefore, contribute materially to local dust deposition or atmospheric pollution.

Cleaning of Castings

Up to a few years ago the fabric filters were almost exclusively used for the collection of dust from shot blast cabinets and centrifugal blasting equipment. Wet type collectors are being installed more frequently now to serve this equipment and it is quite often stated that one of the reasons for it is past experience with the disposal of dry dust from fabric filters. The dust load from the casting cleaning equipment is very heavy and, unless automatic mechanical devices are fitted to a fabric filter unit, the maintenance of its performance is rather troublesome. Dust produced from abrasion cleaning operations has a high proportion of very fine particles and, if cyclones or wet dedusters are employed, it is important to ensure that the air passing through the collector is discharged at a sufficient height outside the building and not returned to the shop atmosphere.

Dressing of Castings

Dust from stand and swing frame grinding machines contains a higher proportion of large particles than dust generated by portable grinders and chipping hammers. To collect dust from the first two types of grinding machines high-efficiency or tubular cyclones are used, as well as wet type collectors and fabric filters; but for the collection of dust from portable tools fabric filters are usually employed.

Pattern Shop

Dust from woodworking machinery is usually separated in a cyclone type of collector.

Dust Disposal

Dust disposal can create a secondary dust problem if not tackled correctly, and it has been mentioned already that the difficulties experienced in some steel foundries in connection with the disposal of dry dust has resulted in a changeover to wet type collectors. It is a common arrangement to discharge the dry dust from the hopper directly onto a lorry. Some of the fine dust which becomes airborne during this procedure might be blown back into the shop and, on a windy day, a cloud of dust will accompany the lorry on its way to the refuse dump. Effective wetting of dry dust as it leaves a collector or storage hopper is difficult. Some steel foundries have overcome this difficulty by discharging the dry dust into paper bags, which are tied up when full and disposed of in a normal way.

With wet collection the major disposal problem is the selection of transport equipment that will eliminate spillage. The water supply and waste water disposal should also be taken into consideration.

Location of Dust Collectors

It is not an uncommon practice, in particular in the case of small dust collecting units, to install them inside the shop close to the dust generating equipment or operation. If the exhaust fan is connected to the outlet end of the collector the unit is under negative pressure and any leakages in the collector will result in drawing the shop air into the unit. With the exhaust fan on the inlet side of the collector (cyclones), the latter is under positive pressure and if the unit shows any leakage it will be the very fine, respirable size of dust

that will escape into the shop atmosphere. This has been observed on several occasions.

Attention should be paid to the location of the discharge stacks from the dust collectors. The discharged dust and fume can be blown from exhaust stacks back to the shop through open windows and doors. The use of stacks sufficiently high to guard against the possibility and to ensure effective dispersion of any dust of fine particle size passing through the dust collectors is very important.

Cost of Dust Collection

It can be seen from Tables I and III, prepared by Stairmand[44], that dust collectors are available which will collect a fine dust containing particles smaller than 5 microns, with efficiencies ranging from 65% to almost 100%, at a total cost from about 0·01 to 0·22 pence per 1,000 cu. ft. of gas treated. It is clear that the higher the efficiency required the more costly is the operation of cleaning the gas, and this emphasises the importance of keeping the exhaust rates down to the minimum values consistent with effective local ventilation and control of the dust.

APPENDIX XXII

Carbon Monoxide

Joint Standing Committee on Conditions in Iron Foundries

1. The Joint Advisory Committee on Conditions in Iron Foundries[5] did not directly discuss the amount of carbon monoxide that might be present in foundry atmospheres but the sections on Open Fires, Ladle Drying and Heating, Mould Drying and Mould Core Stoves clearly envisaged the danger. We therefore remitted the whole subject to our Sub-Committee and our comments on it are based on their work. It may be true that there has been comparatively little trouble from this source in existing foundries in this country, but it is also probably true that this immunity is accidentally conferred by unintended ventilation. We think, however, that the subject requires some attention in modern foundries which are housed in good buildings with the proper heating and controlled ventilation recommended in the report of the Joint Advisory Committee[5].

The Cupola

2. More carbon monoxide is produced by the cupola than by any other source in the foundry, the stack fumes containing from 10% to 15% of this gas. Most of the carbon monoxide leaves the cupola at the top of the stack but some may escape through the charging door. Many charging platforms are in the open air and this may account for the relative absence of gassing accidents. On the other hand, the Joint Advisory Committee recommended that "roof cover as complete as possible should be provided to protect men from the weather", adding the caution that "the arrangements should be such as to ensure that the ventilation is sufficient to prevent gas from collecting over the platform".

The presence of carbon monoxide in the foundry atmosphere around the cupola base was first reported in Sweden where the cold winter climate had necessitated buildings of a high standard of construction with permanently closed doors and controlled systems of general ventilation. In the restricted atmospheric conditions so produced the leakage of carbon monoxide from cupolas became a serious matter and it was shown that concentrations as high as 0·1% might occur around the base of the cupola. Our Sub-Committee discussed the possibility of carbon monoxide leaking from cupolas into the foundry atmosphere and at their request, the British Cast Iron Research Association did a good deal of work on various aspects of the matter and some of the results were published in 1954[49].

Heating Stoves and Open Fires

3. Coke-burning stoves for space heating are used either with a flue discharging the products of combustion into the open air or with a flue terminating in the foundry. It is usually suggested that this latter method must be used because flues extending to the foundry roof would prevent the passage of overhead cranes. It is obvious that any carbon monoxide produced will pass into the

foundry atmosphere if the stove is not fitted with a flue which leads to the outside air. No experimental work has been done in the slow combustion stoves for the purpose of this report, but it is known that "natural draught" coke fires will give up to 10% carbon monoxide in the products of combustion[49] and it may be that this figure will be exceeded for a short time after filling the fire with a charge of cold coke. While we are aware that Section 3 of the Factories Act, 1937 requires the provision of proper flue systems for these stoves, we are of the opinion (on purely technical grounds) that they should always be fitted with flues to take the products of combustion to the open air.

Coke braziers have been used to heat foundries and often enough no flue system has been provided. This has been prohibited since 1st January, 1956 by Regulation 7(1) of the Iron and Steel Foundries Regulations, 1953. No experimental work has been done for your Committee on the carbon monoxide content of the products of combustion of these braziers used at floor level but tests taken from braziers sunk below floor level in a mould cavity have shown[48, 49] a concentration of carbon monoxide as high as 0·86% with a CO/CO_2 ratio of 0·022.

Core Stoves

4. It has not yet been possible to make any tests on core stoves but there is little doubt that dangerous concentrations of carbon monoxide can be generated in the stoves. Generally this is a matter of no significance because the flue gases pass to the open air. On the other hand some carbon monoxide may enter the foundry atmosphere if stove doors are left open when the fires are burning.

Poured Moulds

5. Poured moulds are a further source of carbon monoxide if the vents are not lighted and also after lighted vents have gone out. Concentrations of 0·045% carbon monoxide have been recorded in samples taken close to mould vents which have not been lighted[48] and in one case an unlighted vent stream gave 0·224% carbon monoxide.

These figures may be insignificant if a small number of boxes are in this condition in a well-ventilated foundry, but may merit consideration in foundries engaged in continuous pouring. We have not estimated the carbon monoxide content in the foundry atmosphere from this source, other work having been done in preference, because we did not consider that the poured boxes constituted a major risk in British foundries. On the other hand, it should be appreciated that they contribute carbon monoxide to the general atmosphere of the foundry and vents should always be lighted. Obviously a continuous casting process will produce more carbon monoxide from this source than the intermittent casting of small numbers of boxes.

Mould Drying

6. The Joint Advisory Committee recommended that "no ordinary open fire should be used for mould drying other than in exceptional cases where it can be shown to be unavoidable"[5]. They appreciated that flue systems could not be fitted to portable mould dryers, but on the information then available took the view that little risk could be anticipated from their use. In consequence, they recommended the use of portable mould dryers to the exclusion, wherever possible, of the open fire for mould drying.

In view of the remark of the Joint Advisory Committee that they had "not been able in the time available to make exhausitve tests"[5] and because they indicated that their information only "tended to confirm that there would be little risk of injurious or offensive fumes or smoke"[5] from portable mould dryers, we referred the whole subject to our Technical Sub-Committee. A good deal of experimental work has been done for this Sub-Committee by private firms and by the British Cast Iron Research Association in order to determine the amount of carbon monoxide that might be present in the products of combustion from both open fires and mould dryers. The Sub-Committee carefully examined the results and have now presented us with their Report[48], which has already been published.

The Report of the Joint Advisory Committee referred to the use of radiant heat for mould drying, and also recommended that "sufficient stove capacity should be provided to take all work which can be stove dried", but neither of these methods was discussed by our Sub-Committee. They closely examined, however, three other points raised by the Joint Advisory Committee. These were (1) the use of open fires for mould drying; (2) the use of portable mould dryers for mould drying; (3) the divergence of opinion amongst foundrymen as to the range of work over which the mould dryers can be used. The first two points involved extensive analyses of the products of combustion from different types of mould dryers operating in different conditions. This work has been completed and used by the Sub-Committee as a basis for recommendations which are reprinted in Appendix XXIII. The third matter is still under consideration. The Sub-Committee is in agreement with the remark in the Report of the Joint Advisory Committee that "experience and skill would be required before they (mould dryers) could be applied successfully to all types of moulds". The Sub-Committee are satisfied that mould dryers should be used and consideration is now being given to the possibility of preparing a report which would indicate the best methods of applying them to a mould and show also some of the practices used by experienced foundrymen to overcome difficulties in mould drying by means of portable dryers.

The question of combustion is discussed in the published Report[48] and we think that this document warrants the close attention of all those who are interested in the manufacture or use of portable mould dryers. It contains general discussions on such matters as the CO/CO_2 ratio, types of coke, depth of fuel beds, air supply and the completeness of combustion. It also has seventeen appendices which give the results of the experimental work that has been done.

Open Fires

7. Gas analyses were made on the products of combustion from open coke fires which had been placed in pit moulds in the normal fashion for the purpose of mould drying[48]. It was found in one case that the carbon monoxide concentration inside the mould rose to a figure as high as 0·62%. The Joint Advisory Committee discussed the nuisance caused by smoke from open fires used in mould drying, but quite apart from this aspect of the matter, we are satisfied that braziers in the confined space of a pit mould may give sufficiently high concentrations of carbon monoxide to be dangerous to people entering the mould and we have no doubt that open fires should not be used for mould drying, except in exceptional circumstances, and then only if adequate precautions against gassing are taken.

Coke Fired Portable Mould Dryers

8. Most of the experimental work was done on coke fired portable dryers and carbon monoxide determinations were made on fan blown dryers and on dryers which used induced air from a compressed air ejector system. The dryers were tested under a wide variety of conditions and efforts were made to obtain the maximum possible concentration of carbon monoxide.

To this end many of the trials were tested in conditions chosen to give incomplete combustion. The full results are given in the report already mentioned[48], but the Sub-Committee concluded that "mould dryers gave much less carbon monoxide than open fires and therefore we consider that the latter should not be used except where their use can be shown to be unavoidable. Although appreciable concentrations of carbon monoxide may be evolved from mould dryers, none of the dryers examined showed dangerous concentrations even in the worst period following the charge of cold coke, provided that the back pressure was less than 1 in. water gauge. This condition can readily be fulfilled if adequate free outlets are provided from the moulds".

Gas-fired Portable Mould Dryers

9. One series of tests was done on a gas-fired mould dryer operating against a back pressure of 1·9 in. water gauge[48]. Even in these conditions the carbon monoxide concentrations were substantially lower than those given off from coke fired dryers and this was true in all operating conditions. The Sub-Committee commented that "probably the main risk from gas-fired dryers comes from the risk of leakage of unburnt gas from the flexible connections".

The results of this work on mould dryers justified the recommendations of the Joint Advisory Committee on the subject. Recommendations of the report on the drying of moulds by portable dryers[48] are reprinted in Appendix XXIII.

Electric Mould Dryers

10. We have noted with interest the development of electric mould dryers in foundries overseas. No objectionable fumes or gases escape from these dryers and where they can be used they give the best atmospheric conditions. For this reason we should welcome their introduction into British Foundries.

Ladle Drying

11. Many of the considerations which apply to mould drying also apply to ladle drying and the problem has been passed to our Technical Sub-Committee. It has not yet been possible to examine it in the same way and we have nothing at present to add to the recommendations of the Joint Advisory Committee.

APPENDIX XXIII

Recommendations from Report on the Drying of Moulds by Portable Dryers

1. No ordinary open fire should be used for mould drying other than in exceptional cases where it can be shown to be unavoidable.
2. Hard cupola coke is the most suitable fuel, whilst hard furnace coke is also suitable. Gas coke is less satisfactory.
3. The coke should be graded and the size should not be less than 1½ inches. The size range from 2 inches to 3 inches, when free from fines, gives the best results.
4. Gas coke in the size range less than 1 inch is definitely unsuitable and should not be used.
5. Manufacturers of mould dryers should ensure that the depths of the fuel bed is not such as to produce excessive carbon monoxide in the products of combustion.
6. Coke should be charged frequently and in small quantities, or alternatively a controlled feeding device should be employed.
7. Manufacturers should ensure that the fan will overcome the resistance of the dryer and the mould.
8. The fan should supply a sufficient volume of air to the dryer.
9. Valves should be simple in operation.
10. Valves should be designed so that they remain operative in spite of dirt and rough handling.
11. Where separate valves control the primary and secondary air it should not be possible to shut off the secondary air completely.
12. The grate should be designed to allow of easy clinkering and cleaning.
13. The grate of the dryer should be kept clean and clinker or ash should not be allowed to accumulate on it.
14. Mould dryers should be used in such a fashion that there is as little restriction as possible between the dryer outlet and the mould outlet.
15. The end of the main discharge pipe from the dryer should be not less than 1½ times the pipe diameter from the nearest protection plate or mould surface.
16. The total area of the discharge openings from the mould should be not less than 1½ times the area of the dryer discharge pipe. If this cannot be ensured by the use of the runners and risers, or by wedging up the cope, then a "lift out" piece should be provided to give the required area.
17. The cross sectional area of any ducting between the dryer and the mould should be not less than the cross sectional area of the dryer outlet.
18. If bends are included in any ducting between dryer and mould, they should be of the full duct diameter and round rather than abrupt; it should not be forgotten that a right angle bend reduces the effective cross sectional area of the pipe to seven-tenths its original area, so that pipe diameters should be correspondingly increased as the angle between the arms of the bend decreases.

19. A CO/CO_2 ratio of not more than 0·05 should be obtained within 5 minutes of recharging the dryer with cold coke.
20. A CO/CO_2 ratio of not more than 0·02 should be obtained within 10 minutes of recharging the dryer with cold coke.
21. These ratios should be obtained when the dryer is working at the makers' stated rate, and discharging against a back pressure of 1 inch water gauge in the discharge pipe.
22. Low sulphur coke should be used to minimise the production of sulphur dioxide.
23. When controlling the temperature of the exit gases by adjusting the valves, the combustion rate should be high enough to maintain a brightly incandescent fuel bed.
24. The mechanical design should be simple, so that even after much use or neglect, the dryer will function correctly.
25. The dryer should be designed so that it can be lifted in safety.
26. Initial lighting of the dryer should be safe and simple.
27. Wherever possible an initial charge of brightly burning coke should be used to avoid smoke, and the fuel bed should be built up gradually to the recommended height.
28. Wide fluctuations in the proportions of fuel and air should be avoided.
29. Mould dryers should not be used in confined, unventilated spaces.
30. When the discharging gases from a mould escape through a single opening, it is probably worth while fitting a short pipe to the opening so that the gas discharge will be above breathing level.
31. Manufacturers should issue clear and simple instructions on the use of dryers and these instructions should be readily available to operators. This might be achieved by affixing instruction plates to all dryers. Strict compliance should be maintained with the makers' instructions when using dryers.

APPENDIX XXIV

Core Binders

Joint Standing Committee on Conditions in Iron Foundries

1. The Joint Advisory Committee on Conditions in Iron Foundries[5] drew attention to the irritating and objectionable fumes that may be given off when certain kinds of binders are used in core making, and remarked on the possibility of a health risk in one specific case. We decided that further work was necessary on this complicated matter before any useful opinion could be expressed. We remitted the whole subject of core binders to our Technical Sub-Committee, which has indicated several approaches to the problem, namely (1) the development of new core binders which would give no objectionable products of decomposition, (2) the careful and correct use of existing binders so that a minimum amount of fumes would be generated, and (3) the use whenever practicable of ventilating devices to control fumes after they have been generated.

These three lines of approach were set out in a different order in an earlier publication[52]. The Sub-Committee did not give much attention to the third method, because it was thought that exhaust ventilation could well be applied in suitable conditions, one example being the use of ventilating tunnels after casting on a conveyor belt in a mechanised foundry. There are, however, occasions where local exhaust ventilation is impracticable, and in these cases the first and second methods become the most important. A report of our Sub-Committee findings on the second method has been published[52] and so far as the first method is concerned, we have noted with interest the introduction of a new carbon dioxide process in connection with the making of moulds and cores.

Abstract of Literature

2. Our Sub-Committee was fortunate enough to receive much assistance from an interested iron founder who is also an organic chemist. He prepared for us an abstract of existing literature on the break-down products of many materials used as core binders. This abstract[53] was published in 1949 and, together with a second abstract[79], published in 1956, will serve as a basis for future work.

The Reduction of the Amount of Fumes from Oil Bonded Cores

3. The Joint Advisory Committee has remarked in Section 47 of their Report that "More attention to technical control of operations in core shops seems to be needed"[5]. Our Sub-Committee has published a series of recommendations[52] on the subject. The reasons for these are discussed in the text which deals with the storage of binders, the size distribution of the sand, the temperature of the sand, mixing, the storage of the mixed sand, baking, casting and types of core or moulds. We are of the opinion that this document warrants careful consideration and a summary of the recommendations is reprinted in Appendix XXV.

Synthetic Resins

4. Our Sub-Committee also dealt with the use of synthetic resins and a member of the Sub-Committee published a survey of the subject[54] in 1949. As a result the Institute of British Foundrymen set up a Technical Sub-Committee under the Chairmanship of Mr. G. L. Harbach. They reported on the subject[55] in 1951. The following conclusions were reached[55].

> "As to implementing the recommendations of the Garrett Report (i.e. the report of the Joint Advisory Committee) the Sub-Committee is of the opinion that P.F. (i.e. phenol formaldehyde) resin approaches the ideal of a practical and fumeless core binder. Nevertheless the economic attractions of U.F. (i.e. Urea formaldehyde) resin and the fact that fumes from the cereal portion of the mixture are inevitable whichever resin is used, emphasise that good ventilation together with the use of minimum percentage binder and thoroughly baked cores are the most practical means of improving conditions in foundries."

The matter is still receiving attention and while at the present time we can do no more than endorse this conclusion, other work will have to be undertaken in the light of later developments.

Analysis of Fumes from Core Binders

5. Our Technical Sub-Committee has been dealing for some years with the question of analysis of the fumes from core binders. It is a difficult matter because it is not easy to collect the fumes some of which are gases, while some may be in the form of a mist of liquid droplets. Again, when the fumes are collected the organic analysis is extremely complicated and calls for a high degree of skill and patience from the analyst. Further, the products of decomposition differ with different binders and it might be expected that identical results will not be obtained in two cases where the same binder is used for different castings in different conditions. Presumably, the heat content of the sand surrounding the metal will influence the composition of the break-down products from the core binders.

Experimental work was started at Loughborough College[56], but for a variety of reasons this effort had to be abandoned. Our Sub-Committee then gratefully accepted an offer from a foundryman which has resulted in a method of collecting the products of decomposition from binders in sufficiently large quantities for chemical analysis[80].

APPENDIX XXV

Recommendations from Technical Report on Practical Methods of Reducing the amount of fumes from Oil Bonded Cores.

General

1. Attention should always be given to the technical control of operations in all core shops.
2. The importance of the mixing operations should not be under-estimated.
3. A high standard of good housekeeping should be maintained in the core shop and in the core sand mixing plant.
4. The number of mixtures used should be reduced to a minimum.
5. All operators should be provided with full and clear instructions.
6. The extravagant use of binders should be avoided.
7. The core binder suppliers should be consulted in the choice and use of binders.

Storage of Core Binders

8. Proper storage should be provided for binders and, in particular, extremes of temperature should be avoided; also, in the case of powders, dampness should be avoided. Old stocks should be used first.

Sand

9. Careful consideration should always be given to the grade of sand to be used, which should be selected with regard to the properties which will be required of it.
10. The proportion of clay and other fines should be restricted to the minimum needed for the work.

Sand Temperature

11. Sand should be cooled before mixing.

Mixing

12. All mixtures should be made on the basis of weight.
13. Semi-solid additions should be weighed.
14. Full details of each mixture should be determined.
15. Strict control should be exercised to ensure that there is no deviation from the specified mixture.

Storage of Mixed Sand

16. Proper storage should be provided for mixed core sand to ensure conditions which reduce to the lowest possible level the rate of evaporation of the moisture.

Baking

17. Cores should not be used in an underbaked condition.

18. The most satisfactory baking cycle should be ascertained and subsequently followed rigidly.

19. So far as is possible cores of a similar size should be baked together.

20. Every effort should be made to avoid the constant opening and shutting of batch stove doors.

21. Fuming cores should be cooled either in the cooling chamber of the stove or under a hood provided with efficient exhaust ventilation.

22. Efficient stoves provided with means for recording and controlling temperature should be used.

23. Stoves should not be heated by an ordinary open fire.

24. Adequate and suitable flue systems should be fitted to all stoves to ensure that the fumes from the stoves do not enter the foundry or core shop.

Casting

25. All vents should be lighted after casting.

Types of Cores

26. "Shell" cores should be used wherever possible to replace large solid cores.

Core Block Moulding

27. The minimum possible quantity of binder should be used.

28. Moulds should be cast under a hood fitted with efficient local exhaust ventilation.

APPENDIX XXVI

Shell Moulding

Joint Standing Committee on Safety, Health and Welfare Conditions in Non-Ferrous Foundries

1. This is a relatively new process and in consequence it is by no means easy to make final and specific recommendations at the present time. On the other hand, it is now in use as a production process and so we have discussed the matter in an effort to reach some interim conclusions which may be of use to the industry. In general, we think that the process represents a definite advance so far as conditions are concerned, and we have no doubt that it will result in less dust in dressing shops because the very good surface finish that can be obtained, together with the close limits of size tolerance that are practicable, should reduce the amount of dressing to be done. At the same time there appear to be certain points in the process which would require attention if the best conditions are to be obtained.

Dust and Fumes

Dust or fumes may appear at the following points in the process:

1. The mixer;
2. The dump box;
3. Pattern spraying;
4. Shells;
5. Casting;
6. Knock-out;
7. Sand recovery.

There is less dust with the use of pre-coated sand.

The Mixer

2. If pre-coated sand is used there will be no mixing process in the foundry. Where sand is mixed with resin a large amount of dust may be produced.

Fine grained sands are normally used containing only very small amounts of clay. The sands are generally separated from natural deposits and may be water washed and air scrubbed during the process of separation. In consequence, most of the fine material will normally have been removed before the sand is used for shell moulding. The amount of dust present from the sand is therefore likely to be much less than that from conventional dry sand moulding methods.

At the same time, the shell process uses a smaller quantity of sand than the conventional methods of moulding, so that this results in a still smaller quantity of dust.

The resin with which the sand is mixed is very finely ground and contains a proportion of hexamethylene tetramine. We have no size range analyses but we do not doubt that the resin particles are small enough to become

airborne. We do not know what possible physical effects the resin may produce, but we think that the matter might be the subject of a medical investigation.

Large quantities of dust are produced when mixing the sand. About one-quarter of one per cent. paraffin may be added in order to reduce the segregation of sand and resin after mixing and if this is added to the mixer it reduces the amount of dust produced when mixing. There is still, however, an appreciable dust cloud when charging the mixer.

We think that the mills should be provided with well fitting covers, so arranged that the resin can be added without removing the cover. Local exhaust ventilation may be necessary at the openings of the chutes through which the resin is charged and the mill is discharged.

Dump Box

3. Dust is produced when the dump box is charged and on each occasion when the pattern is removed after investment. This dust should be controlled by local exhaust ventilation.

The Pattern Plate

4. Fume is given off when the plate is sprayed and may also appear from the plate itself when it is not covered by the shell. This may be due to the emulsion sprayed on to prevent sticking, or it may be due to fragments of sand and resin adhering to the plate. Local exhaust ventilation should be applied to control these fumes. We are informed that these fumes, together with the vapours arising from the stripping solution, can produce headaches and lassitude in the operators.

The Shell

5. The plate is worked at about 250°C and part of the shell reaches a similar temperature. Partial decomposition of the resin and the hexamine occurs and the fume produced may have to be controlled by local exhaust ventilation. This fuming ceases as soon as the shell is cold.

Casting and Knock-out

6. Copious fumes are evolved on casting and at first these fumes burn. Later the flames die out and the products pass into the foundry atmosphere. We know neither the analysis of these fumes (which will differ from that of the low temperature decomposition fume given off when curing the shell) nor the effects they may produce in the operators, but the matter is worthy of a medical investigation. In the meantime, we know that fumes are unpleasant and so we think that they should be controlled by local exhaust ventilation so that they do not pass into the general atmosphere of the foundry.

As the shell burns away there is no real knock-out process. Dust arises when the castings are removed and it is desirable that this be controlled. Where the castings are removed at the pouring point the exhaust ventilation used when pouring will serve to control this dust if so designed.

Sand Recovery

7. Used sand may be recovered after the resin has been burnt out. This process produces fumes which should not be allowed to pollute the foundry atmosphere. Suitable flue systems should be arranged to take the fumes out of the foundry.

Dermatitis

8. It appears from practical experience in shell moulding that the resins in the hot conditions produced by the process may cause skin irritation followed in some cases by a rash. Precautions must therefore be taken to maintain a high standard of cleanliness. The following recommendations in use in one foundry have greatly reduced the amount of trouble from skin complaints which was appreciable in the early days of the process and have in consequence considerably improved the health and the efficiency of the department.

1. Before commencing work in the morning and in the afternoon lanoline is used on the arms and hands. This is well massaged into the skin and not just smeared on.
2. Moulders and assemblers must wash thoroughly at mid-day, stripping to the waist, and washing away all traces of the material from arms, hands, face, neck and chest.
3. Each operator is supplied with a white boiler suit which must be worn. These overalls are changed twice weekly by the foreman.
4. Moulders are supplied with cotton gloves which must be worn next to the skin under the asbestos mitts provided. These cotton gloves are changed daily.
5. The use of shower baths as often as possible, is strongly recommended.
6. Signs of skin trouble or burns are reported to the surgery immediately.

9. We are also informed that the Medical Officer of another foundry recommends that employees should wash with cold water before putting on the barrier cream in order to keep the pores closed and that people who are susceptible to skin irritation or who have had a previous history of skin trouble should not be employed on this process.

Tidiness and cleanliness in the shop are essential. Open containers should not be used, and the fine resin and sand may cause contamination of the shop atmosphere because of draughts if lids are not provided. Floors should be swept up if sand or residues are spilt because the dust will become airborne as a result of the passage of men through the shop if it is allowed to remain on the floor.

Recommendations

1. Local exhaust ventilation or other suitable methods should be applied to control the dust produced when mixing the sand. This may be facilitated if the mills are provided with well fitting covers and the dust which is produced during the processes of charging and discharging the mill should be controlled by local exhaust ventilation.
2. Local exhaust ventilation should be fitted so that the dust which arises from the dump box is not dissipated into the general atmosphere of the foundry.
3. Local exhaust ventilation should be provided to control the fumes which arise from the pattern plate both when it is being sprayed and when it leaves the stove with the shell.
4. The fumes which arise from the shell when cooling should also be controlled at source.

5. The fumes which arise on casting should be controlled by means of local exhaust ventilation.
6. Suitable arrangements should be made to control the dust which arises when the castings are removed from the sand at the knock-out stage of the process.
7. If sand is recovered by burning out the resin, suitable flue systems should be arranged to take the resulting fumes out of the foundry.
8. In order to control dermatitis, full use should be made of such washing and bathing facilities as are provided.

APPENDIX XXVII

Carbon Dioxide Process

Joint Standing Committee on Safety, Health and Welfare Conditions in Non-Ferrous Foundries

1. In this new process silica sand, of the type normally used for core making, is mixed with sodium silicate and moulded into shape. The mould is then treated with carbon-dioxide which reacts with the sodium silicate to produce sodium carbonate and a silica gel which binds the sand grains together. Because water tends to soften the surface, mould facings may be suspended in spirit. The organic spirit is then burnt off after the facing has been applied to the mould. The mould itself may consist of a hardened face only, backed by green sand from the floor, and in these cases the amount of dry material in the mould is relatively small if the castings are knocked out quickly. Some difficulty is still being met with knock-outs and de-coring in certain cases because the sand moulds and cores set very hard. In consequence efforts are being made to improve the break-down properties by adding organic materials.

Fumes

2. Fumes may appear at two stages in the process. Organic solvents may be used when spraying the facing material on to the mould so that the solvent itself may vaporize and pollute the atmosphere, and the decomposition products will pass into the atmosphere when the solvent is burnt off after the facing has been applied. We have no specific information as to the health risks which may result from this part of the process, but we think that it warrants further investigation and there can be no doubt that the fumes should be controlled until they can be shown to be safe. Clearly they will have to be controlled in any case if they appear in large quantities or if they are objectionable in any way. From the view point of the foundry atmosphere it is of course generally better to apply the wash by means of a brush or a swab. The second source of fume will be during the casting and cooling period, and possibly also at the knock-out if organic materials are added to improve the break-down properties of the cores. Once again we have insufficient information as to the nature and toxicity of the fumes which may be produced. It appears that the materials which are being added are very similar to those already in use in core making and we can only stress the need for further work, both chemical and medical, along the lines suggested by the Sub-Committee of the Joint Standing Committee on Conditions in Iron Foundries.

In any case, fumes which appear during or after casting or at the knock-out should be controlled by local exhaust ventilation where it is practicable and if local exhaust ventilation cannot be applied at present a high standard of general ventilation should be provided.

Dust

3. The sand normally used is core sand which will have been washed, and perhaps air scrubbed in preparation. There should, therefore, be very little

fine-grained material in the sand; we think that new sand will he largely free from dust although, if the sand is reclaimed after knock-out or de-coring processes, this may be no longer true. In fact if the de-coring processes involve the use of power-operated tools, the sand may well contain appreciahle quantities of silica particles within the respirahle size range.

Dust may be produced during the sand mixing process and this should certainly he controlled if it appears in any quantity. If and when sand is re-used it should be analysed for particle size range and chemical composition. This will be necessary to determine the amount, if any, of free silica within the respirahle size range. It seems that the full silica content of the used sand in the small size ranges will depend on the nature of the process and the treatment that is necessary when knocking-out and de-coring. Clearly if free silica is present in the respirahle size range the dust will have to be carefully controlled by local exhaust ventilation.

The dust produced at the knock-out operation should he controlled hy one or other of the means suggested in the section on knock-out[3]. We are in no position to access the risk hecause we know neither the size range, nor the chemical composition of the dust that might he produced. We think that this dust should be examined with a view to determining the health risk hecause this kind of information might well modify our conclusions.

One of the main difficulties encountered in the use of the process has heen caused hy the difficulty of hreaking down the cores after casting. This difficulty will vary with the degree to which the core has heen heated hy the molten metal and in extreme cases the sand may have fritted. We think, therefore, that the de-coring process should he considered separately from the knock-out. This process can sometimes he done without producing much visihle dust, hut we have no information as to the amount of fine dust which might he produced. We think this is of some importance because the small size range particles which constitute the silica hond may he separated from the sand grains at this stage. If this separation does occur, very fine silica may he present in the atmosphere and if it is, the size range and concentration of this material should be determined.

Quite apart from the silica from the bond, if cores are so hard that they have to be hroken down hy mechanical tools, such as pneumatic chisels, the sand grains will be comminuted into small particles and this will give rise to a well-known risk from the use of these tools on castings bearing sand. It is still too early to make any dogmatic statements, but we think that local exhaust ventilation should he applied as it is for dressing processes if difficulty is encountered in de-coring and we have no doubt that much more information is needed before we can recommend with certainty.

Recommendations

1. The fumes which arise from the use of organic materials in spirit washes should he controlled hy local exhaust ventilation.
2. Fumes may he given off during casting and at the knock-out process if organic materials have heen added to the mould or cores to improve the hreak-down properties. These fumes should be controlled at source hy local exhaust ventilation.

3. The dust which results from the knock-out process should be controlled and the methods of doing this are discussed in the section on knock-out.
4. Dust which is produced by dressing operations should be controlled by ventilation or other suitable means. This whole subject is discussed in some detail in the section on dressing.

APPENDIX XXVIII

TABLE I

Steel Foundry Accidents 1953–1956*

General Summary

Classification Group	1953	1954	1955	1956
1. Power Driven Machinery	83	71	64	68
2. Hoisting Appliances	130 (1)	94 (1)	84	114
3. Falls of Persons	120 (1)	95	93	109 (1)
4. Burns	93	72	84	91 (1)
5. Eye Injuries	103	90	88	73
6. Portable and Hand Tools	100	111	100	92
7. Handling Materials	349	312	321	292
8. Falling Articles	268	228 (1)	214 (1)	248
9. Stepping On: Striking Against	82	70	102	78
10. Electrical	4 (1)	—	2	6
11. Transport	11	33 (3)	45	35 (1)
12. Miscellaneous	12	49	9	22
Totals	1,355 (3)	1,225 (5)	1,206 (1)	1,228 (3)

* Figures in brackets indicate fatal accidents.

TABLE II

FOOT INJURIES

	1953		1954		1955		1956	
1. Power Driven Machinery		8		5		1		3
2. Hoisting Appliances		24		25		21		32
3. Falls of Persons		19		12		7		5
4. Burns:								
(*a*) Molten Metal	21	36	22	34	27	38	24	31
(*b*) Others	15		12		11		7	
6. Hand Tools		3		9		14		8
7. Handling Materials		20		24		26		28
8. Falling Articles		194		175		157		159
9. Stepping On: Striking Against		33		27		25		12
11. Transport		3		8		12		9
12. Others		—		2		1		1
Totals		340		321		302		288

TABLE III

BURNS (excluding Eye Injuries)

	1953	1954	1955	1956
(*a*) Molten Metal:				
(i) Furnaces	5	7	12	10
(ii) Transporting	13	11	10	5
(iii) Pouring	26	22	19	31
(*b*) Other Explosions	10	8	5	10
(*c*) Welding, Cutting, etc.	14	12	8	13
(*d*) Other Hot Substances	18	17	14	16
(*e*) Miscellaneous	7	12	15	6
Totals	93	89	83	91

TABLE IV

EYE INJURIES

	1953	1954	1955	1956
(*a*) Portable and Hand Tools (except abrasive wheels)	41	35	30	27
(*b*) Grinding or Blasting	22	20	18	14
(*c*) Welding or Cutting	7	5	4	3
(*d*) Molten Metal	6	7	7	6
(*e*) Others	27	23	29	26
Totals	103	90	88	76

APPENDIX XXIX

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APPENDIX XXX

Acknowledgments

Numbers refer to the illustrations in this Report.

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